Assistance at parturition of primiparous, two-year-old, Angus heifers and the effect of liveweight gain of heifers in early pregnancy on birth weight of the calf

A thesis presented in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

in

Animal Science

at Massey University, Palmerston North, New Zealand.

Rebecca Edith Hickson

2009

ABSTRACT

Hickson, R. E. Assistance at parturition of primiparous, two-year-old, Angus heifers and the effect of liveweight gain of heifers in early pregnancy on birth weight of the calf. PhD thesis, Massey University, Palmerston North, New Zealand. 212 pp. 2009.

A simulation showed that calving heifers for the first time at two compared with three years of age increased profitability of a beef breeding herd; however, profitability of calving two-year-old heifers was dependent on the incidence of assistance at parturition. The predominant cause of dystocia (and hence assistance at parturition) in beef breeding heifers is feto-maternal disproportion. This condition could be alleviated by reducing birth weight of calves relative to live weight of heifers. In a survey of farmers, 20% of those currently calving heifers at three years of age indicated that if the need for assistance at parturition was eliminated, they would calve their heifers at two years of age. In two surveys conducted of the same farmers in consecutive years, mean incidence of assistance at parturition in primiparous, two-year-old heifers was 7.0% and 9.5%, and reached 100% in some herds. Mortality rate by four weeks postpartum was 30% for assisted calves and 11% for assisted heifers. Methods of reducing the need for assistance at parturition in primiparous, two-year-old, beef breeding heifers would be of value to the beef cattle industry in New Zealand.

The objective of this research was to identify whether manipulation of liveweight gain of primiparous, two-year-old, Angus heifers in the first trimester of pregnancy could be used to regulate birth weight of calves, and to identify factors contributing to the need for assistance at parturition. Three experiments were conducted in which heifers were fed for various rates of liveweight gain: 1. moderate versus low for the first trimester of pregnancy; 2. a 2 x 2 factorial experiment in which liveweight gain was 1220 high versus moderate for ten days prior to insemination, and moderate versus a loss for the first trimester of pregnancy; 3. high and moderate, moderate and a loss, or moderate and moderate for days 0–42 and 42–90 of pregnancy, respectively.

Birth weight of calves was not affected by treatment in experiments 1 and 3. In experiment 2, birth weight of the calf relative to live weight of the heifer was least in the high-then-low treatment, but subsequent live weight of those calves was also less,

partially negating any potential benefits to production. An additional experiment revealed similar fetal weight at the end of the first trimester for heifers that had moderate or low liveweight gain from 21 days prior to conception.

Probability of assistance at parturition increased with birth weight of the calf and decreased with increased live weight of the heifer. Body dimensions of calves did not affect the likelihood of assistance. Assistance had no effect on subsequent performance of surviving animals.

Manipulation of liveweight gain of heifers in the first trimester of pregnancy did not offer a means of reliably regulating birth weight of calves; however, the impact of assistance at calving did not justify delaying first calving until three years of age. Birth weight and assistance at calving can currently be best managed through selection of appropriate service sires for primiparous heifers.

ACKNOWLEDGEMENTS

In three and a half years working on this project, I have had the opportunity to work with a long list of wonderful, talented people, and I express my sincere appreciation to them all. In particular, I have benefitted from the guidance of Steve Morris, Paul Kenyon and Nicolas Lopez-Villalobos, who have made a huge contribution not just to this thesis, but to my development as a scientist. Thank you.

I gratefully acknowledge the financial support of Massey University and Meat and Wool New Zealand for funding the major research projects, and of AGMARDT and LIC for the provision of my doctoral scholarships. Funding from the McGeorge Research Fund and the Lewis Fitch Veterinary Research Fund is appreciated, as is the contribution of resources from Ambreed Ltd, AFFCO Manawatu, Country-Wide Publications Ltd, and the Angus, Hereford and Simmental breed societies.

The experimental component of this work has involved long hours and hard work by many people. Of particular value were Phil Brooks and Jono Brophy of Massey University's Tuapaka farm, whose patience and good humour in the face of numerous tedious and inconveniently timed tasks played a key role in the success of this project. The enthusiasm and dedication displayed by Kim Fraser has also been invaluable! The assistance of Dean Burnham, Graeme Poole, Ross Bagley, Neil Smith, Geoff Purchas and Andrew Wall is much appreciated. Special mention must go to Davy, Oliver and Valerie Garland and Christie Balcomb, four of the finest stockpersons I know, and to Fraser Mulvaney (a.k.a. "Placenta Claus"), who showed up to help out every time he was asked, even with the most unpleasant tasks. Also thank you to Warren Anderson and Cord Heuer for assistance with the survey and to Barrie Ridler for use of and help with the Grazing Systems Model. There was also an enormous contribution made by the heifers, without which there would have been no project.

I've had the privilege of sharing this experience with a fantastic group of post-graduate students (especially Erica, Christine, Cecilia, René, Dannie, Jeremy, Folusho, Kavitha, Jo, Kathryn and Gina), who made both the office and the field a lot of fun. I'm grateful to Dr Tricia Johnson for setting such a fine example, and to my father, Peter Garland, for introducing me to all that is beef cattle farming (including dystocia in heifers!).

And finally, I have immense appreciation for the unwavering practical and intangible support of my husband, William Hickson. I began this thesis as Rebecca Gale, and I am thrilled and honoured to finish it as Rebecca Hickson.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND NOTATION

Abbreviations

EBV Estimated breeding value

DM Dry matter

LSM Least squares mean

CI Confidence interval

s.e. Standard error of the mean

Notation

D*n* The *nth* day of the experiment, with D0 being the first day of insemination for heifers in the experiment. Negative values of *n* refer to days prior to the day of insemination.

L*n* The *nth* day of lactation, with L0 being the mean day of parturition for the heifers considered.

HM Heifers fed for high liveweight gain for 10 days prior to insemination and for moderate liveweight gain for the first 93 days of pregnancy (chapter 6)

HL Heifers fed for high liveweight gain for 10 days prior to insemination and for liveweight loss for the first 93 days of pregnancy (chapter 6)

MM Heifers fed for moderate liveweight gain for 10 days prior to insemination and for moderate liveweight gain for the first 93 days of pregnancy (chapter 6)

ML Heifers fed for moderate liveweight gain for 10 days prior to insemination and for liveweight loss for the first 93 days of pregnancy (chapter 6)

Introduction

Calves are the major productive output of beef breeding cows. Efficiency of calf production is determined by the weight of calf weaned per breeding cow, and can be improved by increasing the total number of calves or the weight of individual calves. Calving beef breeding heifers at two instead of the traditional three years of age is an effective way of increasing efficiency of calf production in a beef breeding cow herd (McMillan and McCall 1991) because it increases the total number of calves. Calving heifers at two years of age has its challenges, however, and one of these is the increased incidence of dystocia in these dams (Baker *et al.* 1981). The increased dystocia in heifers both deters farmers from calving heifers at two years of age (Carter and Cox 1973), and decreases the productivity of heifers calved at two years of age (Rice 1994). Consequently, there would be considerable benefit to the beef cattle industry in New Zealand if the incidence and severity of dystocia in primiparous two-year-old heifers was decreased.

The predominant cause of dystocia in two-year-old heifers is feto-maternal disproportion, which refers to the condition in which the fetus is too large relative to the size of the heifer to allow parturition to occur without assistance, or without impairing the viability of the heifer and/or the calf (Meijering 1984; Rice 1994). Thus, the incidence and severity of dystocia in two-year-old heifers could be reduced by identifying methods to reduce the birth weight of calves relative to the live weight of heifers.

This research examined the impact on profitability of a beef herd of calving heifers at two instead of three years of age, and quantified the impact of the need for assistance at parturition on that profitability (Chapter 2). Two nationwide surveys were carried out to document the prevalence of and justification for breeding heifers at 15 months of age in New Zealand, and the incidence and outcomes of assistance at parturition (Chapters 3 and 4). The experimental component of this thesis investigated the impact of maternal liveweight gain in the first trimester of pregnancy on birth weight of calves and the subsequent performance of heifers and calves during the rearing period (Chapters 5, 6 and 7). These experiments were supported by examination of fetal weight at the end of the third month of gestation (Chapter 8). Two further experiments were conducted to identify factors other than birth weight of the calf and live weight of the heifer that contributed to an increased risk of assistance at parturition (Chapters 9 and 10).

The majority of chapters in this thesis have been published in refereed scientific journals. A consequence of this approach has been that there is considerable overlap in the introductions to some of these chapters to allow them to stand alone as published papers. Publications arising from each chapter are indicated on the title page of each chapter.

The experiments described were carried out at Massey University's Tuapaka farm (15 km east of Palmerston North, New Zealand; latitude 40° 20' south, longitude 175° 43' east; Chapters 5, 6, 7, 8 and 9), Keeble farm (5 km southeast of Palmerston North; latitude 41° 24' south, longitude 175° 36' east; Chapters 8 and 10) and Riverside farm (10 km north of Masterton, New Zealand; latitude 40° 50' south, longitude 175° 37' east; Chapters 5 and 6). Heifers were grazed on a mixed sward of *Lolium perenne* and *Trifolium repens* throughout all experiments.

The experiments were conducted over three years using heifers purchased through commercial channels each year. Within year, the heifers were related as follows:

2005

- Heifers that conceived to a single insemination were used in the experiments reported in Chapter 5

2006

- Heifers that conceived to the first insemination were used in the experiments reported in Chapters 6 and 9
- Heifers that conceived to the second insemination were either used in experiment 1 reported in Chapter 8, or the experiment in Chapter 10

2007

- Heifers that conceived to the first insemination were used in the experiment reported in Chapter 7
- Heifers that conceived to the second insemination were used in experiment 2 reported in Chapter 8

All experiments were approved by the Massey University Animal Ethics committee (protocols 04/147 and 06/125).

CHAPTER 1

Review of literature: genetic and nutritional influences on dystocia in primiparous, two-year-old, breeding heifers

Publications arising from this chapter:

Hickson RE, Morris ST, Kenyon PR, Lopez-Villalobos N.
Dystocia in beef heifers: a review of genetic and nutritional influences.
New Zealand Veterinary Journal 54, 255-64, 2006

Productivity of beef breeding cows in New Zealand

The productive output of a beef breeding cow consists of her weaned calves and her own carcass at the end of her life. Feed is the major input required by the beef breeding cow and much of this feed is used to meet energy requirements for maintenance (Ferrell and Jenkins 1985). Energy requirements for maintenance are dependent on liveweight of the cow, and are incurred largely independent of the output of calves. Therefore, methods of increasing the weight of calf weaned from the breeding cow herd relative to the live weight of the breeding cows would be of benefit for increasing the productivity of the beef herd.

Weight of calf weaned can be increased by increasing the mean live weight or the number of calves weaned from the herd. The use of terminal sires offers a means of increasing the mean live weight of calves without increasing the live weight of the cows, and this has been adopted on many farms (Charteris and Garrick 1996). Number of calves weaned is dependent on the number of cows joined with bulls, the pregnancy rate of those cows, and the survival of calves from conception to weaning. The most immediate method of increasing the number of calves weaned per cow in the herd is to increase the proportion of cows that are joined with a bull. Gestation is approximately 282 days in cattle, and the typical post-partum anoestrus period is 80-100 days in beef cattle, so it is not feasible to increase the number of joining periods beyond one per year per cow. The most obvious way to increase the number of cows joined with a bull is to put the replacement heifers to the bull at 15 months of age, instead of the traditional age of 27 months. This creates an opportunity for the cows to produce up to one extra calf in their lifetime.

Breeding heifers at 15 months of age

Carter and Cox (1973) advocated breeding 15-month-old beef heifers as a method of increasing the efficiency of calf production and the rate of genetic gain achieved. In order to best utilise this technique, the future performance of the heifers must not be compromised by the extra demands imposed on them by their first calf. Particularly, heifers must conceive in the subsequent joining period if there is to be any additional value from breeding them for the first time at 15 months (Carter and Cox 1973; Probert 1989).

In order for breeding heifers at 15 months of age to be viable, satisfactory pregnancy rates must be achieved (McMillan 1994). Morris *et al.* (1993) reported that 77% of heifers joined with a bull were diagnosed pregnant, and 96% of those produced a calf. Heifers selected for high 13-month live weight had a calving rate of 78% at two years of age, whilst heifers from the control line had a 74% calving rate (McMillan *et al.* 1992). Morris *et al.* (1986a) reported a pregnancy rate of 73% for Angus heifers bred at 15 months. In the same experiment, Friesian-cross heifers bred at 15 months achieved a pregnancy rate of 93% after an eight-week joining period (Morris *et al.* 1986a). McFadden *et al.* (2004) reported that 90% of rising-two-year-old beef heifers examined to determine pregnancy status by veterinarians at 50 veterinary practices in New Zealand were diagnosed pregnant. This was comparable with the pregnancy rate of 91% for mature cows (McFadden *et al.* 2004). A conception rate of 56% per cycle was calculated for the heifers, compared with 55% for the mature cows (McFadden *et al.* 2004). These results indicated that 15-month old heifers are capable of achieving adequate reproductive rates.

Reasons previously cited for not breeding heifers at 15 months of age included inadequate pregnancy rates, an increased incidence of dystocia and unsatisfactory rebreeding performance (Carter and Cox 1973; Smeaton 1983; Nicol and Nicoll 1987). Additionally, if rising-two-year-old heifers are pregnant, they become priority stock, and must be preferentially fed at the expense of other classes of stock, whereas a herd of non-pregnant, rising-two-year-old heifers can be used as a buffer mob and offered feed above their maintenance ration only when there is surplus feed available (Nicol and Nicoll 1987). Hanly and Mossman (1977) reported that only 9% of maiden heifers joined with bulls in the Wairoa region of New Zealand in 1970–71 were aged 12–15 months and this percentage declined to reach 2.5% in 1973–74, highlighting a trend away from breeding heifers at 15 months. Hanly and Mossman (1977) attributed this to increased "costs in terms of dystocia and poor reproductive ability as second calvers," because 30–80% of heifers that calved at two years of age were diagnosed non-pregnant at the end of the subsequent joining period.

It is widely recognised that two-year-old heifers are at increased risk of dystocia relative to both mature cows and heifers calving at three years of age (Philipsson 1976a; Nix *et al.* 1998; Dargatz *et al.* 2004). Concern about dystocia is one factor that deters farmers from joining heifers with a bull at 15 months of age; thus, preventing these farmers from benefiting from the increased production that could be achieved by calving heifers at two instead of three years of age.

The current situation

There were 516,813 beef heifers recorded as between one and two years of age in New Zealand in 2003, of which 157,549 (30%) were reported to be pregnant (Anonymous 2003). The inclusion of heifers that were destined for slaughter in the total reported in this census skews this estimate of the percentage of heifers calving at two years of age, so it indicates a lower limit on the prevalence of calving two-year-old heifers. In 1993, a survey of farmers in the Waitomo region of New Zealand revealed that heifers were bred at 15 months of age on 48% of farms (Parminter *et al.* 1993), whilst in 2005, a survey of farmers in Canterbury revealed that heifers were calved for the first time at two years of age in 61% of herds (Thomas *et al.* 2007). Current data relating to on-farm management of heifers in New Zealand is scarce.

Dystocia

Dystocia is the term used to describe calving difficulty, and may be defined as a birth in which the level of assistance required to enable completion of the birth process is above the level deemed desirable for the management situation (Meijering 1984). In extensively managed, grazing heifers, which are the norm under New Zealand conditions, any assistance at calving is undesirable (Meijering 1984), and consequently the definition from Rice (1994) of dystocia being "a birth that reduces calf viability, causes maternal injury, or requires assistance" is more appropriate to the situation.

Classification of dystocia

Dystocia is usually classified on scales ranging from two to five classes (Philipsson 1976a). The subjective nature of dystocia classification can make comparisons between studies difficult, due to differences in interpretation of dystocia. The two-category scale compares assisted versus non assisted births (Laster 1974; Johanson and Berger 2003), whereas the more complex, five-class scales consider the degree of assistance required and, sometimes, the cause of the dystocia (Naazie *et al.* 1989; Bellows *et al.* 1994; Meadows *et al.* 1994; Paputungan *et al.* 1994; Whittier *et al.* 1994; Nix *et al.* 1998; Burnham *et al.* 2000).

In addition to dystocia scores, measures of calf viability, such as time from birth to suckling (Rice 1994), and maternal health, such as incidence of retained fetal membranes, may be used to assist in the identification of cases of dystocia. The extent to which dystocia has reduced calf viability or caused maternal injury is often difficult to ascertain in field conditions, so the degree of assistance required is the only measure of dystocia available in many cases (Philipsson 1976a). The criteria that determine whether assistance is necessary vary among stockmen and among studies, but may include time since presentation of membranes at the vulva (Rice 1994; Dargatz *et al.* 2004), time without any visible progress in parturition (Bellows *et al.* 1994) and appearance of a fetal malpresentation (Dufty 1973). Beef cattle farmers in the United States of America left their heifers for an average of 2.8 hours and cows for 3.5 hours after labour activity was observed before rendering assistance (Dargatz *et al.* 2004).

In a review of dystocia, Rice (1994) found that cows that calved unassisted did so within 34 minutes, and heifers within 55–58 minutes, of the appearance of membranes at the vulva. Of the unassisted heifers, those with above-average pelvic areas calved faster than those with below-average pelvic areas. Previous recommendations for time from appearance of membranes before assisting parturition were two hours for cows, and longer for heifers to allow expansion of soft tissue. Rice (1994) recommended providing assistance to cows 30–60 minutes after the appearance of membranes, and to heifers within 60–90 minutes. Earlier assistance can be beneficial to the fetus because pressure exerted against its head by the pelvis and birth canal can cause hypoxia whilst the birth canal relaxes sufficiently to allow its passage (Rice 1994). Wythes *et al.* (1976) reported that farmers who observed their heifers more frequently at calving assisted more heifers than other farmers, but the number of heifer and calf deaths were similar between the inspected and non-inspected herds. This indicates that farmers who observed heifers more closely at calving may have assisted more heifers than needed to be assisted.

Incidence of dystocia

Dystocia is one of the most important causes of calf losses at or near the time of birth (Everitt and Evans 1970; Dufty 1972b; Philipsson 1976a; Montgomery 1978; Morris 1994; Nix *et al.* 1998). Rice and Wiltbank (1972) reported variation in both the incidence and type of dystocia seen in two spatially distinct herds of Hereford heifers. At one location, 27% of the heifers required assistance, and 81% of dystocia was due to fetal malpresentation; whilst at the other location, 52% of heifers required assistance and 81% of dystocia was due to feto-maternal disproportion (Rice and Wiltbank 1972). Both the heifers and the calves were heavier at the second location than at the first location. In younger, Angus heifers (average age 94 weeks), the incidence of dystocia was 83%, with vulval stenosis and vaginal constriction accounting for 55% of these cases (Rice and Wiltbank 1972).

In a survey of farmers in Queensland, Australia, 11% of 23,000 heifers were assisted at parturition and 4% died (Wythes *et al.* 1976). In 35% of the herds, more than 10% of heifers were assisted at parturition, and in 10% of herds, at least 30% of the heifers were assisted (Wythes *et al.* 1976). An extensive study in the United States of America revealed that 69% of all calf deaths between birth and weaning occured in the first 96 hours after birth, of which 65% were attributed to dystocia, based on necropsy lesions (Patterson *et al.* 1987). This may be an underestimate, as it did not include calves that were stillborn as a result of dystocia (Rice 1994). A similar survey by Dargatz *et al.* (2004) revealed that the incidence of dystocia (defined as requiring some assistance) was 17% in heifers and 3% in cows. In a review, Holland and Odde (1992) concluded that perinatal mortality rates in the United States of America ranged from 1-30%, with an average of 3.5-5.0%; and that most perinatal deaths resulted from dystocia, stillbirth or hypothermia. Furthermore, dystocia was found to be the single most important cause of calf deaths (34%) in Colorado, United States of America (Odde 1996). Laster and Gregory (1973) observed a mortality rate of 20.4% for calves that experienced dystocia, compared with 5.0% for calves that experienced a normal delivery.

Research in New Zealand has revealed similar incidences of dystocia to the overseas literature. A study by Morris *et al.* (1993) revealed that of those heifers that calved, 16% experienced dystocia and 11% of the calves were stillborn. Probert (1989) reported that assistance rates ranged up to 29% in survey of Manawatu farms although the majority (58%) of 96 farms surveyed assisted less than 3% of their first-calving two- or three-year-old heifers.

The most important maternal factor affecting dystocia is parity, with the frequency of dystocia and stillbirth 2–4 times greater for primiparous heifers than for multiparous, mature cows (Philipsson 1976a; Nix *et al.* 1998; Dargatz *et al.* 2004). Dufty (1972a) observed that the incidence of dystocia and stillbirths was approximately halved with each successive parturition from primiparous heifers to cows at their third parity. A similar trend was observed in data from New Zealand, in which the incidence of dystocia in two-year-old heifers was twice that of mature dams (Baker *et al.* 1981). Within the first parity, greater than normal frequencies of dystocia and stillbirth have been observed in dams that were very old (greater than three years old) or very young (less than two years old) at first calving; however, these effects varied among breeds (Philipsson 1976a). Age of dam had a significant effect on dystocia, even with adjustment for birth weight (Laster *et al.* 1973; Laster 1974; Bureš *et al.* 2008). The effect of breed on age at maturity was also a factor; dairy heifers showed no benefit in terms of reduced dystocia from calving for the first time at three years of age, compared with late-maturing French beef breeds, which had less dystocia when calved for the first time at three instead of two years of age (Meijering 1984).

In a survey of 53 American Angus herds, Berger *et al.* (1992) found that the percentage of heifers that calved without assistance increased as the heifers increased in age at parturition from less than 23 months to greater than 29 months. Similarly, the incidence of severe dystocia decreased as the heifers aged (Berger *et al.* 1992). The incidence of neonatal mortality also decreased as age of dam at parturition increased (Berger *et al.* 1992). Funston and Deutscher (2004) also observed an increase in dystocia in heifers calving at 22 to 23 months of age compared with heifers calving at 23 to 24 months of age. This may be of relevance to New Zealand conditions, where late-born heifers that calve early in the calving period are likely to be less than 24 months old. There is little scope to delay heifer calving, however, due to the restrictions on calving period imposed by the seasonality of pasture growth.

Consequences of dystocia

Dystocia has immediate consequences and costs for the system, such as increased labour requirements at calving and reduced viability of the neonate (Berg 1979; Meijering 1984; Arthur *et al.* 2000); additionally, there are also longer term consequences. These long-term consequences are more difficult to assess, and include factors such as compromised rebreeding of the dam, decreased performance of the dam and calf, increased calf morbidity and mortality from subsequent disease, and depressed calves that become hypogammaglobulinemic from inadequate or delayed colostrum intake (Rice 1994; Larson and Tyler 2005). The management of heifers likely to experience dystocia is often relatively intensive and requires the use of significant labour and sometimes capital resources. In a survey of 4092 beef cattle farmers in the United States of America, Dargatz *et al.* (2004) reported that heifers were observed, on average, 3.6 times per 24 hour period during calving, with 93% of operators observing them at least once per day. Additionally, 25% of farms used specialised paddocks for heifers to calve in that allowed increased supervision (Dargatz *et al.* 2004). A survey of farmers in the Manawatu revealed that at least one heifer (primiparous two or three year old) was assisted on 80 out of 96 farms (Probert 1989), indicating that a minimum of 83% of farmers surveyed observed their heifers at calving.

Effects on the dam

The repercussions of dystocia for the dam may include reduced milk yield in the following lactation (Meijering 1984), and compromised rebreeding performance including delayed return to oestrus, and reduced conception and pregnancy rates (Philipsson 1976a; Lowman 1979; Meadows *et al.* 1994). Carter and Cox (1973) and Smeaton (1983) identified concerns regarding poor rebreeding performance as a key factor deterring New Zealand farmers from calving their heifers as two-year-olds. Data from both New Zealand and overseas have revealed that two-year-old dams experience a longer intercalving interval than older cows, even when they have a normal calving (Belling 1963; Morris 1984). Therefore, compromised rebreeding performance resulting from dystocia is particularly important in two-year-old heifers, which already experience reduced rebreeding capacity relative to older cows.

Meijering (1984) observed that culling rates were greater among cows that had a difficult parturition or a stillborn calf than among those that experienced a normal parturition. In one study, only 63% of heifers that experienced dystocia calved the following year, compared with 85% of heifers with a normal parturition (Anonymous 1977). Thus, the effects of a difficult parturition on the heifer extended beyond the immediate term and affected her future reproductive performance. Rutter *et al.* (1983) reported that none of the heifers that experienced category-four dystocia (extreme difficulty that involved damage to the dam, caesarean section or death of the calf as a result of delivery) survived in the herd to have subsequent parturitions, as a result of death of the heifer, culling for severe damage to the reproduction tract or failure to conceive to subsequent services.

Laster *et al.* (1973) observed no difference in the incidence of retained fetal membranes following assisted or unassisted parturition in a herd of primiparous, two-year-old heifers and multiparous, mature cows. All cows that required assistance in that experiment were treated with penicillin and streptomycin and given intrauterine antibiotics immediately after parturition, but this did not prevent negative carryover effects of dystocia on the subsequent reproductive performance of the cows – fewer of the cows that required assistance at parturition conceived during the next breeding period (Laster *et al.* 1973), as detailed in Table 1.1. Of the cows that did conceive, the interval from calving to conception was not affected by dystocia, although it was affected by age of the cow (Laster *et al.* 1973). The conception rate for cows that were inseminated was 6.1% less in cows that experienced dystocia than in cows that calved unassisted (Laster *et al.* 1973). Sawyer *et al.* (1991) and Johnson *et al.* (1986) reported no difference in interval to conception between heifers that experienced a difficult or easy parturition.

There were also severe immediate consequences of dystocia that affected the dams involved, the most extreme of which was maternal death (Meadows *et al.* 1994). In a study by Axelsen *et al.* (1981), 16% of the heifers that were assisted at parturition died. Sloss (1974) reported that 10.1% of beef heifers and 7.4% of beef cows in Victoria, Australia, that were assisted by veterinarians at parturition subsequently died. This is likely to be less than the true number of dams that died as a result of dystocia because not all farmers supervised their cows at calving, and a separate experiment showed that the maternal (and fetal) death rate was greater in herds where heifers were left to calve unsupervised (Hodge *et al.* 1982). Dystocia that could be alleviated by correction of position and traction (64.7% of dystocia in beef cattle that was attended by a veterinarian) had the least maternal death rate, whilst fetectomy and caesarean sections both had greater than average maternal death rates (Sloss 1974). Of the cows that died following parturition, 20.9% were slaughtered immediately with no attempt at treatment made (due to low value of the dam relative to the cost of treatment, or the dam being too severely affected to treat), 44.6% were slaughtered after they failed to respond to treatment attempts, and the remaining 34.5% died after failing to respond to treatment (Sloss 1974). A study in New Zealand reported cow deaths of 1% from dystocia (Everitt and Evans 1970).

Table 1.1. Effect of dystocia on percent of cows subsequently detected in oestrus and conception rate (from Laster *et al.* 1973).

Dystocia	Age of cow	No. in group	During AI period[1] Detected in oestrus	Conception rate	Total[2] conception rate
No assistance	2	584	68.3	66.0	79.6
Assisted	2	366	59.3	50.6	71.4
No assistance	2-5	1423	74.3	69.2	85.3
Assisted	2-5	466	59.9	53.6	69.4

[1] The artificial breeding period was 43–45 days, and began 23–27 days after the 70-day calving period.
[2] Total conception rate includes heifers and cows bred during the AI period as well as those bred via natural mating during the 23–27 days after AI that bulls were joined with the cows.

Effects on the calf

Many of the effects of dystocia on the calf relate to its immediate viability, with dystocia an important cause of calf losses at or near the time of birth (Philipsson 1976a; Meijering 1984). Laster and Gregory (1973) reported that neonatal mortality was four times greater in calves that experienced dystocia than in the calves that had not experienced dystocia. In one herd, only 28% of calves that experienced dystocia survived the birth (Sawyer *et al.* 1991). Nix *et al.* (1998) reported mortality rates of 21 to 50% in calves that experienced dystocia of varying severity, compared with 3% mortality in calves that had a normal birth. In Holstein cattle, difficult births were accompanied by perinatal mortality 2.7 times more often than normal births (Johanson and Berger 2003). Calf mortality was 45.5% for calves experiencing a difficult birth compared with 9.1% for all calves born to Israeli Holstein heifers (Bar-Anan *et al.* 1976). Similarly, Axelsen *et al.* (1981) reported that 52% of calves born from assisted heifers died, whilst the herd's overall calf mortality rate was 14%. Calf survival at birth, to 24 hours, to one week and to weaning was less in calves experiencing dystocia than in those experiencing a normal birth (Arthur *et al.* 2000). Calves that experienced dystocia and survived the neonatal period had a greater mortality rate and reduced growth to weaning (Kroker and Cummins 1979; Meijering 1984).

Dystocia may cause hypoxia and acidosis in calves, which may lead to death during birth or severely impair the viability of newborns; affected calves are often slow or unable to stand and suckle (Meijering 1984; Rice 1994). Affected calves lost body temperature soon after birth (Rice 1994), ultimately resulting in death. Fetuses deprived of oxygen for four minutes survived, but those deprived of oxygen for six or eight minutes died (Anonymous 1977). Calves that experienced dystocia commonly had localised oedema of the head and cervical region and atelectatic or haemorrhagic lungs at necropsy (Rice 1994). Traumatic lesions, such as ruptured diaphragm and fractures of the vertebrae, ribs or sternum, were also found (Rice 1994).

Dufty (1973) observed that the time of death of stillborn fetuses varied from four hours to more than twelve hours after rupture of the amnion, with the deaths of all calves attributed to anoxia or asphyxia. Similarly, Laster and Gregory (1973) found that the lungs were uninflated in 80% of calves designated dead at birth. Necropsy was performed on 14 stillborn fetuses by Dufty (1973), who found subcutaneous oedema generally confined to the ventral and lateral aspects of the head, but also occasionally below the fetlocks on both forelegs. Haemorrhages were consistently found spread throughout the body (Dufty 1973).

Types of dystocia in heifers

Dystocia may be caused by factors attributed to the calf and to the dam (Berg 1979), and in many cases is caused by a combination of both calf and dam factors (Philipsson 1976a). Feto-maternal disproportion was the most common cause of dystocia in heifers (Philipsson 1976a; Meijering 1984; Rice 1994; Odde 1996), and fetal malpresentation, vulval/vaginal stenosis and inadequate labour efforts were other important causes (Dufty 1972a). Incidences of types of dystocia in an experiment by Dufty (1972a) are detailed in Table 1.2.

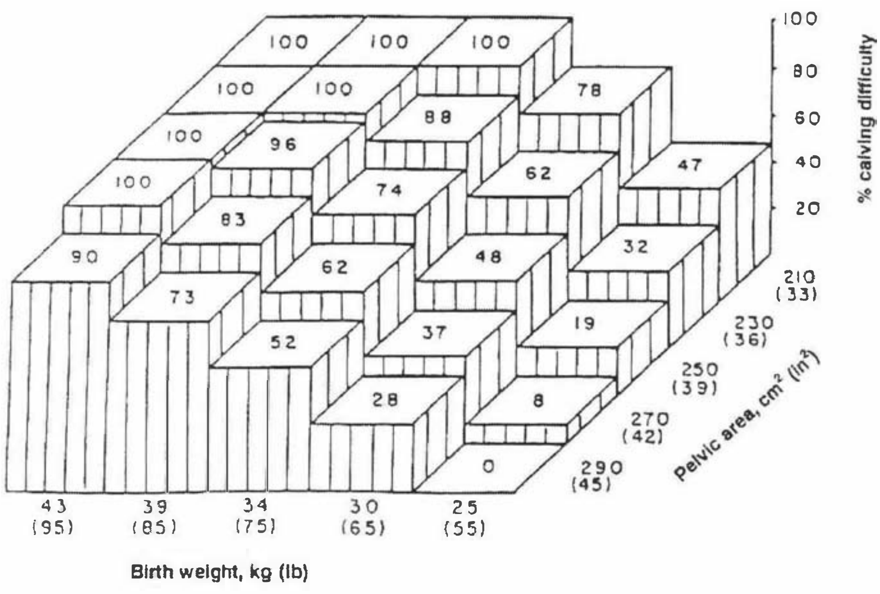
Feto-maternal disproportion

Feto-maternal disproportion was the leading cause of dystocia in beef cattle (Rice 1994; Odde 1996; Nix *et al.* 1998), especially in heifers (Philipsson 1976a; Meijering 1984; Paputungan *et al.* 1994). Feto-maternal disproportion may result from either an oversized fetus or an undersized pelvic area, or both (Philipsson 1976a; Wolverton *et al.* 1991). Dystocia score has been reported to increase as the ratio of birth weight of the calf to live weight of the dam increased (Price and Wiltbank 1978; Johnson *et al.* 1988; Naazie *et al.* 1989; Arthur *et al.* 2000). The relationship between birth weight of the calf, pelvic area and dystocia is illustrated in Figure 1.1. Johnson *et al.* (1988) reported that pelvic area was the maternal trait most closely associated with dystocia in heifers, but birth weight of the calf accounted for more than twice as much of the variability in incidence of dystocia (Rice 1994).

Table 1.2. Percentage incidence of various causes of dystocia and stillbirths in an experimental herd of Hereford heifers that were either confined in a pen during parturition or allowed to calve in a paddock (from Dufty 1972a).

	Parturition conditions		
Condition	**Unconfined**	**Housed**	**Total**
Vulval stenosis and reduced labour activity	14.9	34.1	25.8
Vulval stenosis	-	20.5	11.6
Reduced labour activity	-	6.8	3.9
Feto-pelvic disproportion (anterior presentation)	14.9	-	6.5
Postural abnormalities (anterior presentation)	-	9.1	5.2
Posterior presentation	14.9	15.9	15.5
Fetal membranes	-	9.1	5.2
Twinning	1.5	-	0.7
Unknown	53.7	4.6	25.8

Figure 1.1. Incidence of dystocia in primiparous, two-year-old, beef heifers in relation to birth weight of the calf and pelvic area proportions of the heifer (from Bellows 1984, cited in Odde 1996).



Birth weight

Birth weight is the result of one of the most dynamic growth and developmental processes in mammalian biology, and because gestation length is relatively constant (282 days), differences in birth weight predominantly result from variations in fetal growth rate (Holland and Odde 1992). Birth weight of the calf was the most important factor associated with dystocia in heifers (Philipsson 1976a; Lowman 1979; Rutter *et al.* 1983; Johnson *et al.* 1988; Naazie *et al.* 1989; Meadows *et al.* 1994; Rice 1994; Arthur *et al.* 2000). In contrast, Makarechian *et al.* (1982) reported live weight of the dam to be the factor with most affect on dystocia in cows and heifers, although birth weight of the calf was the second most important factor in that study. Calves that experienced dystocia were heavier than calves that had a normal birth (Arthur *et al.* 2000), and a positive correlation existed between birth weight and duration of birth (Price and Wiltbank 1978). Price and Wiltbank (1978) reported that the incidence of dystocia increased by 3.3 ± 0.34% for every 1 kg increase in birth weight of the calf for two-year-old heifers, whilst Laster *et al.* (1973) reported 2.30 ± 0.21% and Smith *et al.* (1976) reported 1.63 ± 0.20% as the increase in dystocia for every 1 kg increase in birth weight. Similarly, Berg (1979) estimated that the incidence of dystocia increased by 1–4% for every 1 kg increase in birth weight. In contrast, in some studies the incidence of dystocia increased markedly after birth weight reached a certain threshold, indicating a nonlinear relationship (Philipsson 1976a; Meijering 1984; Rice 1994). The threshold above which the incidence of dystocia was markedly increased was dependent on breed, parity and the definition of dystocia used (Meijering 1984). A birthweight threshold of 31 kg was identified for groups of heifers with mean live weights after calving ranging from 286 kg to 362 kg (Wiltbank and Remmenga 1982) and for Angus heifers in a survey of 53 herds (Berger *et al.* 1992). In primiparous Charolais heifers, the birthweight threshold above which dystocia increased significantly was 45.5 kg for male calves and 50 kg for female calves (Rutter *et al.* 1983). Schlote and Hassig (1979) observed that mean birth weight increased with severity of dystocia when dystocia was classified on a 4-point scale. Combinations of live weights of heifers and calves from a range of studies are detailed in Table 1.3 along with the associated incidences of assistance.

Table 1.3. A cross-study comparison of the incidence of assisted parturition in relation to breed and mean live weight of the heifer and mean birth weight of the calf.

Reference	Breed of heifer	Live weight of heifer (kg) and day of weighing	Birth weight of calf (kg)	Incidence of assistance (%)
Hodge and Stokoe 1974	Hereford	344 8 days before calving period	25	36
	Hereford	342 8 days before calving period	26	7
	Hereford	351 8 days before calving period	27	11
Laster 1974	Mixed	349 20-25 days before calving season	31	42
Berg 1979	Hereford	328 Within 2 days post calving	31	59
	Synthetic	367 Within 2 days post calving	33	41
Drennan 1979	Hereford cross	361 Post calving	31	0
	Hereford cross	335 Post calving	27	15
	Hereford cross	298 Post calving	27	45
Kroker and Cummins 1979	Hereford to Angus bull	419 Immediately pre-calving	27	6
	Hereford to Angus bull	368 Immediately pre-calving	25	5

Calves that were heavy at birth were not only more likely to experience dystocia (Axelsen *et al.* 1981), they also subsequently suffered from an increased incidence of birth asphyxia, metabolic and respiratory acidosis, depressed immunoglobulin absorption and increased susceptibility to disease (Holland and Odde 1992). Conversely, calves that were extremely light at birth may not have experienced dystocia, but they were less viable due to a lack of vigour, low tolerance to cold stress, weak resistance to pathological agents and an impaired ability to overcome birth stresses (Holland and Odde 1992). Therefore, a moderate birth weight is desirable to optimise viability of the calf (Kroker and Cummins 1979; Meijering 1984). In support of this, Carter and Cox (1973) and Morris *et al.* (1986b) reported a greater incidence of neonatal death for both very large and very small calves compared with average-sized calves born to two-year-old heifers.

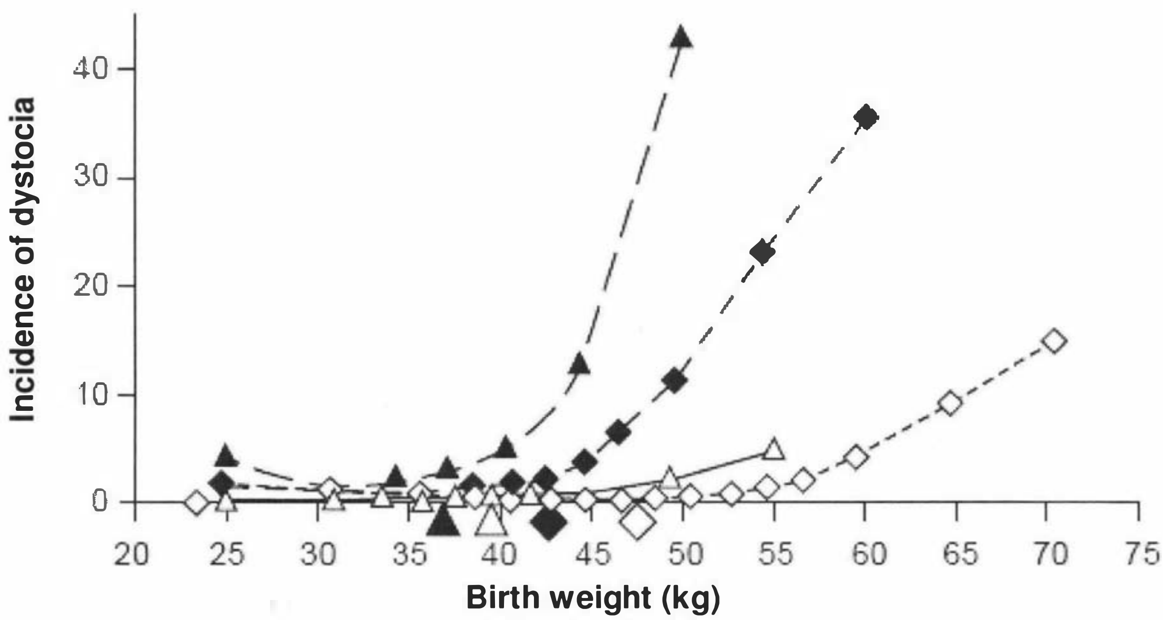
As the size at which birth weight becomes 'too big' is dependent on the size of the dam, Berg (1979) expressed birth weight as a percentage of the dam weight. Table 1.4 illustrates the incidence of dystocia for calves with birth weights at varying percentages of maternal weight. The percentage threshold at which the incidence of dystocia increased was less for heifers than for mature cows (Berg 1979). Similarly, Figure 1.2 illustrates that the incidence of dystocia at a given birth weight was greater for Hereford than for Charolais dams and for dams at first compared with subsequent parities (Eriksson *et al.* 2004b).

Table 1.4. Incidence of dystocia within classes of birth weight of the calf as a percentage of live weight[1] of the dam, by breed and age of cow (from Berg 1979).

	Hereford			Synthetic (Charolais, Angus and Galloway)		
	2 years	3 years	4+ years	2 years	3 years	4+ years
< 7.0	0	0	4	22	0	9
7.0 - 7.9	25	0	2	10	0	0
8.0 - 8.9	52	10	8	26	0	1
9.0 - 9.9	60	29	9	39	3	5
10.0 - 10.9	66	27	27	76	16	10
>11.0	94	67	50	100	14	15

[1] Live weight of cows and calves was recorded within two days of parturition.

Figure 1.2. Phenotypic relationships between dystocia and birth weight illustrated by weighted averages within birthweight intervals for first-parity Herefords (–▲–), first-parity Charolais (-◆-), later-parity Herefords (-△-) and later-parity Charolais (-◇-), where intervals are wider at extremes due to few observations. Mean birth weights are marked as ▲= first-parity Herefords, △= later-parity Herefords, ◆= first-parity Charolais, and ◇= later-parity Charolais (from Eriksson et al. 2004b).

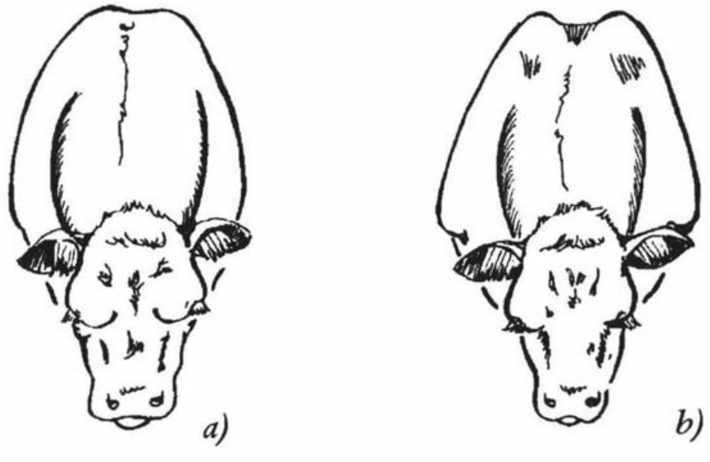


Body shape of calves

The New Zealand beef industry has some focus on shape of the shoulder as a cause of dystocia, and farmers are advised to avoid animals that are wide at the point of the shoulder or have a wide space between the tops of their shoulder blades when they are selecting bulls for breeding (Priest *et al.* 1998), as outlined in Figure 1.3.

Nugent and Notter (1991) examined fetal body dimensions and proportions (including head circumference, shoulder width and hip width) as contributors to dystocia, but these factors were not significant once birth weight had been considered. Similarly, the few differences in body dimensions among calves that required varying degrees of assistance at birth were small and inconsistent (Colburn *et al.* 1997). In a review, Meijering (1984) reported that a range of measurements of height, width and circumference had been made, but birth weight alone accounted for dystocia as effectively as birth weight in combination with any of the body dimensions. Laster (1974) also found no effect of body dimensions on incidence of dystocia. Schlote and Hassig (1979) identified a minor role for body dimensions in dystocia, with the inclusion of thirteen body dimensions increasing a multiple trait correlation with calving performance to 0.47, from 0.37 for birth weight alone.

Figure 1.3. (a) Desirable and (b) undesirable shoulder shapes for bulls (from Cumming 1999).

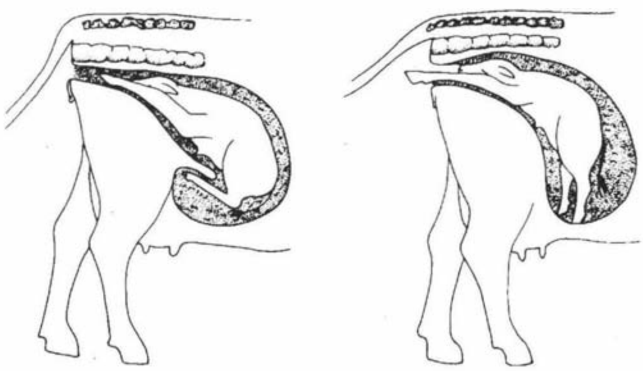


Fetal presentation and posture

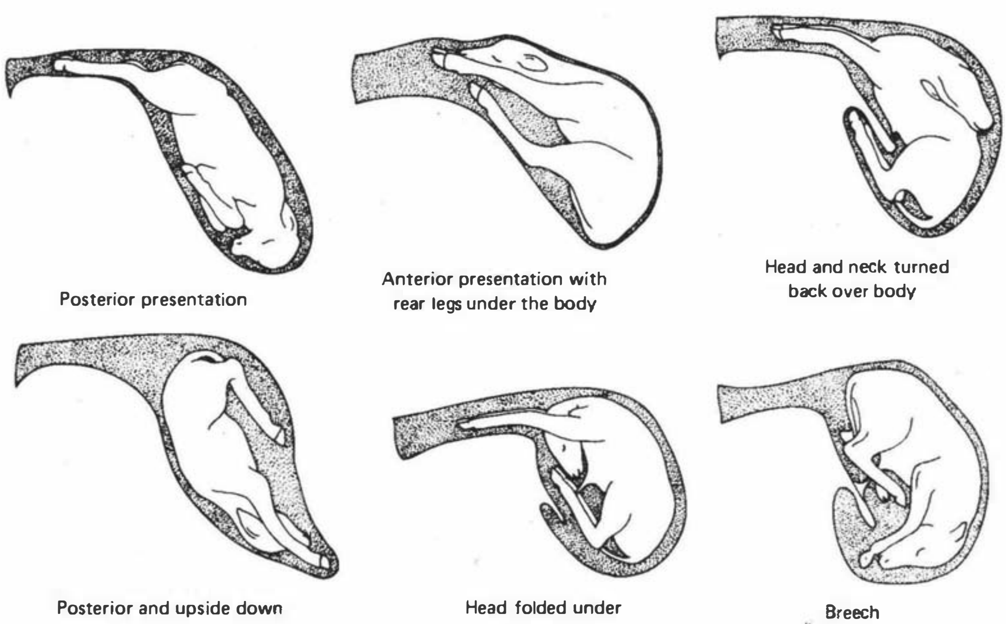
The second most common reported cause of dystocia is abnormal presentation or posture of the fetus in-utero (Rice and Wiltbank 1972; Holland *et al.* 1993; Rice 1994). Abnormal presentation refers to any fetal presentation in which the fetus was not presented with both fore legs followed by the nose into the birth canal; see Figure 1.4 (Sorensen 1979). Any abnormal presentation that delays the more bulky parts of the fetus contacting the cervix contributes to delayed initiation of reflex abdominal straining by the dam, which further impairs the parturition process (Dufty 1973). The incidence of abnormal presentation varied among studies, from 0.9–4.0% of births (Holland *et al.* 1993; Nix *et al.* 1998; Bennett and Gregory 2001a).

Figure 1.4. (a) Correct and (b) incorrect fetal presentation in cattle (from Sorensen 1979).

(a)



(b)



Few factors have been related to the cause of abnormal fetal presentation, with several authors reporting that fetal posture and presentation were dynamic, and presentation was able to change right up until parturition began and posture sometimes changed as late as the first phases of second stage labour (Dufty 1972a; Rice and Wiltbank 1972; Dufty 1973). Dufty (1973) suggested that suboptimal uterine tone contributed to the adoption of a posterior position by one fetus and the displacement of a foreleg by at least one other fetus. Holland *et al.* (1993) reported heritability of 0.003–0.088 for malpresentation as a trait of the calf, and 0.030 to 0.076 for malpresentation as a trait of the dam, indicating only a very minor role for genetic influence on the likelihood of malpresentation.

Vaginal/vulval stenosis

Vaginal and vulval stenosis refer to the failure of the vagina or vulva to soften and stretch to allow passage of the fetus (Rice 1994). This can cause dystocia in cases where fetal size is not considered excessive. Sawyer *et al.* (1991) listed subnormal dilation of the vulva or cervix as one of the important causes of dystocia in primiparous heifers. In normal parturition, the greatest delay in fetal expulsion occurred when the fetal head reached the vulva, although in some heifers, additional contractions were required to push the shoulders and hips through the vulva (Dufty 1972b). The effort required by the dam to push the fetus' head through the vulva was such that in cases of vulval stenosis, the passage of the fetus was halted completely or delayed for several hours while the dam attempted to force the fetal head through the vulva (Dufty 1972b).

An excessive incidence of vulval stenosis observed in heifers penned for observation and clinical examination during calving was suggested to result from excessive stimulation of the sympathetic nervous system caused by intensive management (Dufty 1972b). Rice and Wiltbank (1972) also reported vulval stenosis as a predominant cause (55%) of dystocia in heifers penned for observation at calving. Under New Zealand conditions, heifers are unlikely to be penned at calving, but may be subjected to increased contact with the farmer if the heifers are observed frequently for signs of difficulty. This may cause some stress on the heifers, but to a much lesser degree than that imposed by Dufty (1972b).

Inadequate labour efforts

Inadequate labour efforts refer to circumstances in which there is no obvious cause for dystocia, yet parturition has failed to progress. Australian range heifers confined during calving displayed a much greater incidence of dystocia than their unconfined contemporaries, due to both inadequate labour efforts and vulval stenosis, which was attributed to the stress of being confined in an unfamiliar environment (Dufty 1972b; Meijering 1984). In contrast, Rice and Wiltbank (1972) reported that only one of 93 heifers penned for observation at calving experienced dystocia due to uterine inertia. Uterine inertia was also observed as a cause of dystocia in primiparous heifers by Sawyer *et al.* (1991). A possible explanation for the effect of stress on parturition was that because adrenaline stimulates relaxation of the uterus musculature, the presence of stressors (which cause elevated adrenaline concentration) may result in delayed parturition by inhibiting the tonicity of the uterus (Anonymous 1977; Rice 1994).

Weak labour is also sometimes observed in older cows, often in association with milk fever (Meijering 1984). Philipsson (1976a) suggested that the greater incidence of difficult calvings and stillbirths observed in winter than in spring and late summer births was due to the dams having lesser fitness as a result of being housed in confined spaces with low levels of exercise. This was supported by the results of Lamb *et al.* (1979), who reported that heifers exercised for four weeks prepartum experienced less dystocia than heifers that were housed without exercise; however, Bellows *et al.* (1994) found no differences in dystocia score or incidence between heifers that had been exercised daily for the last trimester compared with those that had been confined. Similarly, Burnham *et al.* (2000) found no difference in duration of parturition between heifers that had walked 5 km per day from day 211 to day 277 of pregnancy and those that were confined in small paddocks during this time.

Dufty (1972b) observed that abdominal contractions eventually stopped in heifers that experienced severe dystocia, despite the fetus still being present in the vagina, although they were initiated again when traction was applied to the fetus. Cessation of contractions during a very prolonged parturition may be termed inadequate labour effort, as the contractions of the dam were not sufficient to expel the fetus; however, the failure of the dam to expel the fetus was due to fetal size and vulval stenosis rather than lack of effort (Dufty 1972b). In contrast, other heifers showed extreme agitation and ceased contractions for periods of up to ten minutes in response to any unusual noise or movement (Dufty 1972b). Although these heifers also experienced vulval stenosis, their inadequate labour efforts were significant factors contributing to their dystocia.

Factors contributing to dystocia in heifers

Dystocia in heifers is caused by many factors that contribute to the various types of dystocia. These can be classified as either genetic or environmental effects. Additional factors that increased the incidence of dystocia showed more dramatic expression when incidence of dystocia was already elevated (Laster *et al.* 1973); for example, the effects of increased birth weight on dystocia were more pronounced if the heifers concerned had below-average pelvic area than if they had average-sized pelvic area.

Genetic factors

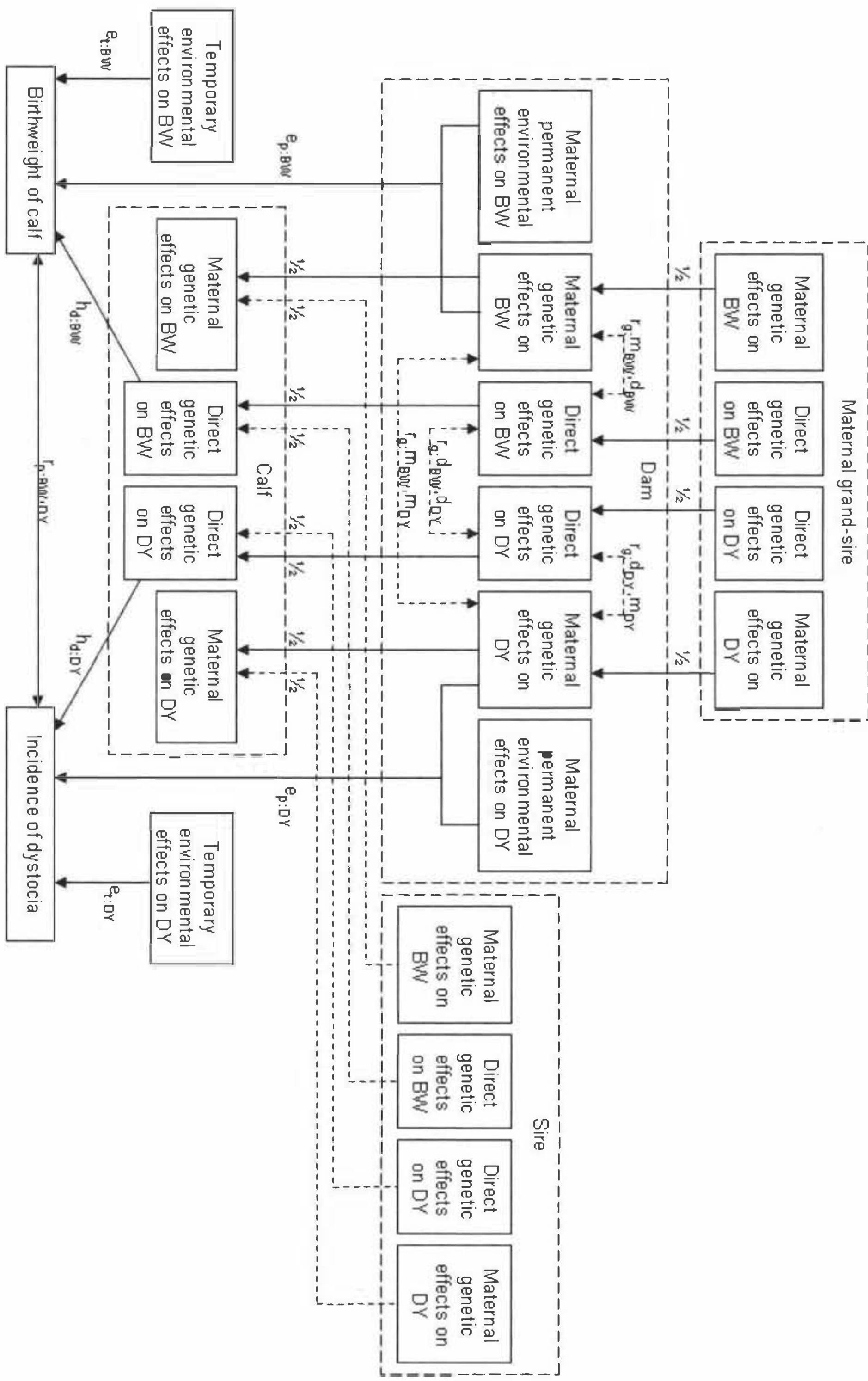
Genetic factors affecting dystocia include both direct and maternal effects (Bennett and Gregory 2001a). Direct genetic effects refer to the genotype of the fetus and its contribution to factors affecting dystocia. Maternal genetic effects that influenced dystocia were those factors regulated by the genotype of the dam that affect the fetus or the incidence of dystocia, such as uterine capacity and pelvic area. The dam's genotype regulates the impact on the fetus of external environmental factors affecting the dam, so that these effects become a combination of maternal genetic effects and environmental effects on the fetus. The genotype of the dam is affected by the genotype of the maternal grandsire, so that both the calf's sire and maternal grandsire influence the likelihood of the fetus experiencing dystocia (Philipsson *et al.* 1979; Rice 1994), as illustrated in Figure 1.5. The heritability of direct genetic effects was greater than the heritability of maternal genetic effects (Bennett and Gregory 2001a), indicating that genetic factors played a greater role in determining whether a calf experienced dystocia than whether a dam experienced dystocia.

Direct genetic effects

Birth weight

Of the factors contributing to dystocia in heifers, birth weight is under the most direct genetic control by the fetus (Cundiff *et al.* 1986), although a multitude of maternal and environmental factors also influence birth weight. Estimates of heritability of birth weight in cattle ranged from 0.10 to 0.50 (Meijering 1984; Baker *et al.* 1990; Holland

Figure 1.5. Genetic and environmental influences on birth weight (BW) and incidence of dystocia (DY). r_g is the genetic correlation between direct and maternal effects, m is the maternal genetic effects, d is the direct genetic effects, e_p is the permanent environmental effects, e_t is the temporary environmental effects, h is the square root of heritability, and r_p is the phenotypic correlation.



and Odde 1992; Hansen *et al.* 2004; Phocas and Laloe 2004; Bell 2005; MacNeil 2005), with many estimates falling in the 0.40–0.45 range (Holland and Odde 1992). This indicated that fetal genotype had a large influence on birth weight.

There was a strong, positive genetic correlation between birth weight and dystocia score (Bell 2005); correlations ranged from 0.9 to 0.98 (Philipsson 1976a; Meijering 1984; Cundiff *et al.* 1986). This correlation meant that selection for decreased dystocia would lead to decreased birth weight in the selected animals (Cundiff *et al.* 1986; Bennett 2008). Low-birthweight heifer calves may themselves be lighter at parturition, and consequently selection for decreased dystocia at birth may contribute to increased dystocia at subsequent parturitions. Positive genetic correlations between birth weight and carcass weight have been identified, and negative genetic correlations between dystocia score as a trait of the dam and dam carcass weight also exist (Eriksson *et al.* 2004). Meijering and Postma (1985) reported that despite being smaller at birth and at parturition, heifers born to easy-calving bulls did not experience a greater incidence of dystocia at parturition than heifers born to bulls considered high risk for dystocia. Nevertheless, positive direct genetic correlations have been identified between dystocia score at birth or birth weight and hip height, pelvic area, age at puberty, scrotal circumference or retail beef yield (Bennett and Gregory 2001b). Bennett (2008) demonstrated that concurrent selection for both reduced dystocia and increased yearling weight achieved both aims, whereas selection for increased yearling weight and maintenance of birth weight resulted in an increase in yearling weight and no change in dystocia.

Heritability of dystocia as a trait of the calf has been reported to be less than that of birth weight, at 0.03–0.37 in heifers (Philipsson *et al.* 1979; Meijering 1984; Naazie *et al.* 1991; Eriksson *et al.* 2004a; Hansen *et al.* 2004), and 0.00–0.27 in cows (Philipsson *et al.* 1979; Meijering 1984; Baker *et al.* 1990; Phocas and Laloe 2003, 2004). When dystocia score was considered in two categories, such as no assistance or 'hand' assistance compared with mechanical or surgical assistance, Cundiff *et al.* (1986) reported heritability of 0.42 in a multi-breed analysis. When breeds were considered individually, heritability of dystocia score decreased to 0.21 (Cundiff *et al.* 1986). Similarly, estimates of heritability were greater when dystocia was differentiated into many classes compared with the simpler assisted or non-assisted classification (Philipsson *et al.* 1979; Bennett and Gregory 2001a). Table 1.5 shows estimates of the heritability of birth weight and dystocia score from a range of studies and populations.

Table 1.5. Estimates of heritability of dystocia in primiparous two-year-old heifers.

Reference	Heritability estimate	
	Calf	Dam
Bennett and Gregory 2001a	0.43	0.23
Eriksson *et al.* 2004a	0.11–0.16	0.07–0.12
Naazie *et al.* 1991	0.28–0.37	0.12–0.47
Hansen *et al.* 2004	0.11	0.07

Birth weights varied greatly among breeds, and there were also large sire differences within breed (Rice and Wiltbank 1972; Price and Wiltbank 1978; Lowman 1979; Meijering 1984; Cundiff *et al.* 1986; Holland and Odde 1992). Carter and Cox (1973) reported that herds that used large sire breeds had greater calf mortality than other herds. The time during gestation at which the fetal weights of different breeds diverge is unknown, but Holland and Odde (1992) suggested that it was likely to occur during the first trimester, as morphological differences between *Bos taurus* and *Bos indicus* breeds were evident by Day 100 of gestation. Several authors have reported a greater incidence of dystocia in Hereford heifers compared with other beef breeds (Laster and Gregory 1973; Sloss 1974; Wythes *et al.* 1976). Greater calf mortality was reported in two-year-old Hereford heifers than in two-year-old Angus heifers in a study in New Zealand, although the causes of the deaths were not reported (Carter and Cox 1973). In a study involving heifers from a range of crossbreeds, Newman and Deland (1991) reported a greater incidence of dystocia in dams that were part European breed, whilst dairy-breed cross animals had less incidence of dystocia. The genetic variability of dystocia score means that there is potential to select for animals with less dystocia (Philipsson *et al.* 1979). Whittier *et al.* (1994) concluded that sires known to produce light calves that have good growth rates could be used to achieve acceptable dystocia incidence and growth rates of calves without requiring a change in breed.

Heterosis can have large effects on birth weight, depending on the breeds involved (Holland and Odde 1992). Heterosis estimates ranged from 0–5% between crosses of standard British or European breeds, and were increased to 7% with the inclusion of a novel breed such as the Scottish Highland (Holland and Odde 1992). Increased birth weight resulting from heterosis was not consistently associated with increased incidence of dystocia (Price and Wiltbank 1978). In contrast, inbreeding generally resulted in lighter calves; and lighter placentae have been associated with inbred Hereford calves

(Holland and Odde 1992). Price and Wiltbank (1978) reported that the reduced birth weights of inbred calves were accompanied by increased incidence of dystocia and perinatal mortality. Placental size is important to birth weight because a heavier placenta is likely to have greater surface area for nutrient exchange (Holland and Odde 1992). It has been suggested that the paternal influence on birth weight is greater than the maternal influence (Garrick *et al.* 1989), possibly because of paternal imprinting of genes that control placental development (Bell 2005); however, other researchers have reported that the dam has the greater effect on birth weight of an individual calf due to her ability to regulate the uterine environment (Rice 1994).

Regardless of whether the sire or the dam has the greater effect on birth weight of the calf, the selection of sire is critical to controlling the influence of dystocia in the herd, as the sire or sire team influence the birth weight of every calf born (Rice 1994). Smeaton (1983) showed that the use of low-birthweight bulls of small breeds to join with heifers allowed the heifers to calve with no additional calving problems relative to mature cows.

Gestation length

Heritability of gestation length was greater than that of birthweight, at 0.61–0.64 (Crews 2006). Genetic correlations between birthweight and gestation length have been reported in the range of 0.20–0.52 (Philipsson 1976b; Crews 2006). Mean gestation length for all breeds was 282 days, and most breeds fell within the range of 278 to 290 days (Joubert and Hammond 1958). Gestation length tended to be longer for male than for female fetuses (Joubert and Hammond 1958; Smith *et al.* 1976; Price and Wiltbank 1978; Holland and Odde 1992; McClintock *et al.* 2005; Crews 2006).

Gestation length was moderately positively correlated with birth weight (Price and Wiltbank 1978; Holland and Odde 1992). Birth weight increased with gestation length by 0.15–0.38 kg/day for different breed groups (Smith *et al.* 1976; Crews 2006), and as a result, calves with longer gestation length tended to have increased incidence of dystocia, although the trend also existed independent of birthweight (McClintock *et al.* 2005). In contrast, Price and Wiltbank (1978) and Schlote and Hassig (1979) reported that correlations between gestation length and dystocia score were generally small and not significant, and Meijering (1984) suggested that any increase in dystocia resulting from longer gestation was more likely to be the result of increased birth weight than gestation length itself. Mortality of calves was greater for calves that had extremely long or short gestations, due to increased size-related dystocia or immaturity, respectively (McClintock *et al.* 2005; Fiedlerová *et al.* 2008).

Gestation length was greater in older cows compared to primiparous heifers (Joubert and Hammond 1958; Smith *et al.* 1976; McClintock *et al.* 2005; Crews 2006). In reciprocal crossbreeding between South Devon and Dexter cattle, South Devon dams carried their calves for 290 days compared with 278 days in Dexter dams, despite both breeds having a mean gestation length of 287 days for straightbreds (Joubert and Hammond 1958). Maternal heritability estimates for gestation length were 0.01 to 0.20 (Philipsson 1976b; Crews 2006). The genetic correlation between maternal effects on gestation length and maternal effects on birth weight was 0.62 (Crews 2006). Bennett *et al.* (2008) observed that gestation length was 1.8 days shorter for cows selected for reduced dystocia score over seven years compared with control lines.

Sex of calf

In addition to genetic merit for birth weight, fetal genotype also determines sex of the fetus (through the presence of XX or XY sex chromosomes) and may affect gestation length. Sex of the fetus influenced the incidence of dystocia significantly, with male calves experiencing dystocia more often than female calves born to heifers (Bellows *et al.* 1971b; Laster *et al.* 1973; Philipsson 1976a; Price and Wiltbank 1978; Lowman 1979; Axelsen *et al.* 1981; Makarechian *et al.* 1982; Meijering 1984; Newman and Deland 1991). This difference was primarily a birth weight effect, as male calves are heavier than female calves (Laster *et al.* 1973; Price and Wiltbank 1978; Meijering 1984; Bureš *et al.* 2008). In addition to experiencing a greater incidence of dystocia, male calves that experienced dystocia were more likely to die in the perinatal period than female calves that experienced dystocia, a trend that did not occur in calves that experienced a normal birth (Laster and Gregory 1973), suggesting that the severity of dystocia experienced by male calves may have been greater than that experienced by female calves.

In some cases, differences between sexes in the incidence of dystocia still existed when adjustments for birth weight were made (Philipsson 1976a; Lowman 1979; Rutter *et al.* 1983). Male calves may have different conformation to female calves, which may contribute to the increased incidence of dystocia in male calves (Price and Wiltbank 1978), however, no relationship has been found between a variety of body dimensions of calves and dystocia (Rice 1994).

Instead, the effect of sex on incidence of dystocia may be caused by differences in the hormones produced by the conceptus (Philipsson 1976a; Rice 1994), although Echternkamp (1993) found no difference in the prepartum circulating concentrations of oestrone sulphate or progesterone between heifers carrying a male or female fetus. Less concentration of oestrogen has been observed in dams that experienced dystocia than in those that had not experienced dystocia (Meijering 1984). The placenta is the source of elevated oestrogen concentration at parturition and differences in fetal genotype may alter dam performance at parturition by affecting production of placental oestrogens (Rice 1994). Oestrogen assists the relaxation of the birth canal and stimulates uterine contractions during parturition. Maternal oestrone sulphate concentration in the ten days prior to parturition was positively correlated (0.65) with birth weight of the calf (Echternkamp 1993). Birth weight of the calf was also positively correlated with a range of placental weight and size parameters (Echternkamp 1993).

Maternal genetic effects

The dam influences the fetus through her direct input into the fetal genotype, but also indirectly by providing the environment in which the fetus develops. Birth weight of the calf was proportional to maternal live weight, and averaged 7% of maternal live weight with a range of 5–10% (Robbins and Robbins 1979). Birth weight varied with age of dam, and was least in two-year-old heifers and gradually increased up to 5–6 years of age, then declined after 9–11 years of age (Price and Wiltbank 1978; Holland and Odde 1992).

Maternal ability may be defined as the physiological capacity of the dam to nurture the developing fetus, independent of the contribution to fetal genotype (Holland and Odde 1992). A study involving reciprocal crosses between large South Devon and small Dexter cattle showed that in the small dams, maternal ability limited fetal growth, whereas in the large dams, fetal genotype was limiting fetal growth (Joubert and Hammond 1958). The calves born to Dexter dams were lighter at birth and had shorter gestation than the calves born to South Devon dams, and differences in live weight were still present at 12 months of age (Joubert and Hammond 1958). The magnitude of the maternal effect on birth weight depended on the size difference between the dam and the sire (Price and Wiltbank 1978), and the greatest differences in fetal size occurred in late pregnancy (Ferrell 1991b). Investigations by Ferrell (1991a) revealed that both uterine blood flow and placental function may have roles in maternal constraint.

Heritability of maternal effects on birth weight was estimated to be 0.10 for calves born to mature cows (MacNeil 2005).

In addition to affecting fetal growth and consequently birth weight, the dam also affects the incidence of dystocia through the effects of her pelvic area and the incidence of vulval stenosis or inadequate labour efforts. These factors are under both maternal genetic and environmental control. Hansen *et al.* (2004) estimated the heritability of dystocia as a maternal trait in Danish Holstein heifers to be 0.07. The maternal grandsire has also been shown to play a role in determining the incidence of dystocia in heifers through the effect on the maternal environment, with maternal grandsire effects having heritability of 0.03–0.20 (Meijering 1984). The ratio of pelvic size to body weight decreased as heifers aged, indicating that mature pelvic size was reached earlier than mature body weight; however, growth of the pelvis was more dependent on weight than on age (Price and Wiltbank 1978). Other heifer conformation traits, including width and height of hips, head dimensions, body length and girth, have also been considered as factors contributing to dystocia, but these were shown to have less correlation with calving performance than did body dimensions of calves (Schlote and Hassig 1979). Naazie *et al.* (1991) reported that there was a negative genetic correlation (approximately -0.40) between dystocia score and live weight of the dam at calving.

Use of pelvic area as a selection tool against dystocia

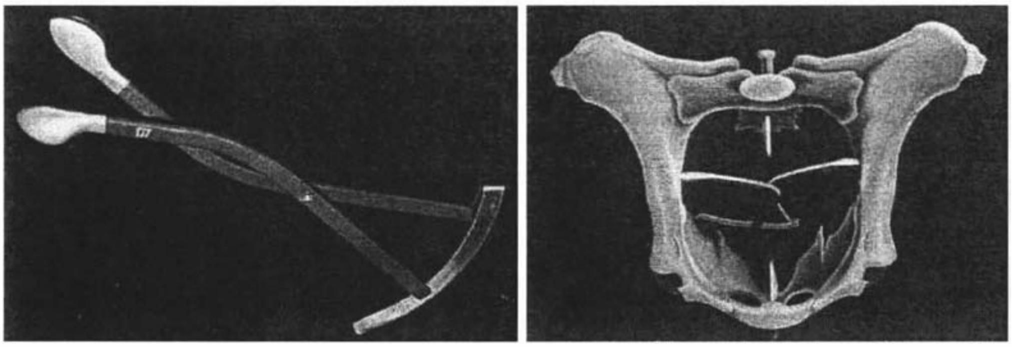
Birth weight is difficult to predict prior to calving, so can not be used to predict dystocia in heifers in advance (Rice 1994). In contrast, pelvic area, the maternal trait with the greatest influence on dystocia, can be measured prior to joining or at pregnancy diagnosis when there is time to selectively cull animals that are likely to experience dystocia. Laster (1974) reported that pelvic area had a significant, but small, influence on dystocia, whilst Arthur *et al.* (2000) reported that it was significant only in a line of heifers selected for low yearling weight. Heifers that experienced dystocia had smaller pelvic area at joining and just prior to calving than heifers that had not experienced dystocia (Axelsen *et al.* 1981).

The most common method of calculating pelvic area is width multiplied by height (Price and Wiltbank 1978; Wolverton *et al.* 1991), although there are other methods, such as assuming the pelvic opening is elliptical (Price and Wiltbank 1978). The method used to calculate pelvic area affects the relevance of the measurement (Price and Wiltbank 1978), and the actual width and heights of the pelvic opening must also be considered, because an extremely rectangular pelvis may be undesirable even with adequate area (Andersen *et al.* 1993). Heifers in which the horizontal pelvic measurement was greater than the vertical pelvic measurement had 9% more 'hard' pulls and 15% more 'questionable' pulls than heifers in which the horizontal measurement was smaller than the vertical measurement, although this difference in dystocia appeared to be the result of differences in calf size rather than pelvic shape (Makarechian *et al.* 1982).

Problems with using pelvic area as a predictor of dystocia are that it is difficult and costly to measure (Figure 1.6), and external measurements have low correlation with internal dimensions (Bellows *et al.* 1971a; Meijering 1984; Wolverton *et al.* 1991; Van Donkersgoed 1992). Heifers can be culled based on minimum standards at the time of measurement (Wolverton *et al.* 1991); however, pelvic measurements made prior to or early in pregnancy are not necessarily indicators of the heifer's pelvic size at parturition, which varies due to hormonal effects on the motility of the iliosacral joints (Meijering 1984; Van Donkersgoed 1992). Pelvic inlet dimensions at parturition show a reasonable correlation (-0.34) to dystocia, but in order to select against animals likely to experience dystocia, the predictor of dystocia must be available well before parturition (Rice and Wiltbank 1972; Rutter *et al.* 1983).

Additionally, other studies have concluded that combinations of pelvic area and expected birth weight of the calf were not accurate enough at predicting whether a heifer would experience dystocia to make them practical measures (Rutter *et al.* 1983; Rice 1994). Van Donkersgoed *et al.* (1990) concluded that a threshold value for minimum acceptable pelvic area was not sufficient as a method of selecting heifers against dystocia, as regardless of the threshold set, there were either many heifers

Figure 1.6. A Rice pelvimeter and pelvic area measurement using a Rice pelvimeter (from Wolverton *et al.* 1991).



selected that should have been excluded (false negatives), or many heifers excluded that could have been included (false positives). Furthermore, Basarab *et al.* (1993a,b) examined a selection of predictive equations tailored for different populations of heifers, and reported that too many heifers were mis-classified for pelvic area measurements at pre-breeding or at pregnancy diagnosis for these to be useful predictors of dystocia.

Other studies concluded that the relationship between pelvic area and dystocia was insufficient to enable accurate prediction of dystocia (Laster 1974), or that there was no relationship at all (Hodge and Stokoe 1974; Hodge *et al.* 1976; Van Donkersgoed *et al.* 1990; King *et al.* 1993). Correlations between pelvic area at calving at 23 months of age and pelvic area at 10, 16 and 22 months were 0.29, 0.43 and 0.52, respectively, due in part to much variation among heifers in the increase in pelvic area observed in the final month of pregnancy (Gaines *et al.* 1993). This meant that whilst pelvic area at parturition was related to dystocia, pre-calving measurements of pelvic area were not significantly related to dystocia (Gaines *et al.* 1993). Similarly, Rice and Wiltbank (1972) concluded that there was insufficient variability in pelvic area at breeding to allow this to be an effective predictor of dystocia.

"Predicted deliverable pounds" has been considered as a measure that can be used to minimise the incidence of dystocia by predicting the maximum likely birth weight that a heifer could deliver based on her pelvic area and selecting a service sire likely to produce a calf lighter than the specified weight (Meadows *et al.* 1994). Heifers delivering calves lighter than their predicted deliverable pounds had fewer cases of dystocia than those delivering calves heavier than their predicted deliverable pounds (Meadows *et al.* 1994); however, assistance was still required by 10-15% of heifers that delivered calves lighter than their predicted deliverable pounds, and by only 24% of heifers that delivered calves heavier than their predicted deliverable pounds (Meadows *et al.* 1994), indicating that predictable deliverable pounds was not a reliable method of predicting or avoiding dystocia. Additionally, this method required prediction of birth weight of the calf to be made at the time of sire selection, which also introduced inaccuracies into the method.

Dystocia rates can be manipulated genetically by selecting for animals with favourable genotypes for direct or maternal effects. There is a negative correlation between the two types of effects, however, so that selecting for direct effects on calving ease results in calves that are born easily, but the heifer calves are likely to subsequently have difficulty calving themselves, possibly because they are likely to be smaller adults

(Meijering 1984; Naazie *et al.* 1991; Rice 1994; Whittier *et al.* 1994). Similarly, pelvic area is positively correlated to frame size, body weight and birth weight, so that selection for increased pelvic area may not result in decreased incidence of dystocia (Johnson *et al.* 1988; Van Donkersgoed 1992). The selection index used for Angus cattle in New Zealand includes both direct calving ease (a trait of the calf) and maternal calving ease (a trait of the dam) in order to optimise the rate of gain in both traits (New Zealand Angus Association 2005).

Environmental effects

In addition to selecting animals for reduced dystocia, dystocia may be influenced by a variety of environmental factors. The fetus is affected by two interacting environments – the maternal environment, particularly the uterine interactions with conceptus tissues; and the external environment, the effects of which are mediated by maternal adaptations to the changing environmental stimuli (Holland and Odde 1992). There are a range of environmental factors that can influence the likelihood of dystocia in heifers, such as geographic location, management and feeding regimen (Wolverton *et al.* 1991), but the one most easily manipulated by the farmer is feed intake (or liveweight gain) during gestation.

Nutrition during pregnancy

Studies investigating the effect of nutrition during pregnancy on dystocia in heifers have produced conflicting results. Severe underfeeding has been shown to reduce birth weight, but also resulted in smaller dams with smaller pelvic areas (Drennan 1979; Kroker and Cummins 1979; Wiltbank and Remmenga 1982), whilst overfeeding resulted in obese dams with a build up of fat in the pelvic region that restricted the passage of the fetus through the birth canal (Rutter *et al.* 1983; Meijering 1984; Van Donkersgoed 1992; Rice 1994). Arthur *et al.* (2000) reported a negative correlation between pre-calving condition score of the heifer and dystocia. In light-weight heifers, pre-calving live weight was significantly negatively correlated with dystocia score, but there was no correlation between live weight of the heifer and dystocia score for heifers that were of acceptable live weight for calving (Price and Wiltbank 1978). Corah (1987) observed that heifers that were well grown at breeding, relative to mature live weight, had less dystocia than light heifers. Nutrition during pregnancy may be especially important in dams that are still growing, as they compete with their fetuses for nutrients

(Wu *et al.* 2004). Underfed heifers (body condition score less than four on a 9-point scale) were more likely to suffer dystocia at calving because they were underdeveloped and weaker at calving (Rice 1994). Laster (1974) found that live weight explained 27.4% of the variation in pelvic area of two-year-old heifers, whilst muscling score, condition score and pelvic slope score explained 0.9, 0.5 and 1.2% of variation, respectively.

A positive correlation exists between birth weight and placental weight (Symonds *et al.* 1998; Heasman *et al.* 1999). Restriction of placental size in sheep by the surgical removal of caruncles prior to breeding has been shown to reduce fetal size (Heasman *et al.* 1999), indicating that placental size may determine fetal size in some situations. This does not eliminate the possibility that in other situations, the fetus may determine placental size, or that both fetal and placental size may be determined by some other factor. Nevertheless, the ability to restrict fetal growth by restricting placental size may enable birth weights to be manipulated through manipulation of the dam's feed intake during the period of placental development. The number of placentomes was relatively fixed by Day 70 of gestation in cattle (Laven and Peters 2001). Mellor (1983) found that total placentome weight in sheep decreased with the number of placentomes, despite increasing weight of the individual placentomes; however, little is known about any nutritional effects on placental development in cattle.

The beef cattle industry would benefit if fetal size at parturition could be regulated by restricting maternal feed intake during some limited period of pregnancy, without impairing post-natal growth of the calf or rebreeding performance of the dam (Prior and Laster 1979). The ability of the farmer to regulate birth weight of the calf through nutrition of the dam during pregnancy is limited by the ability of the dam to use her body reserves to buffer nutrient supply to the fetus. The dam mobilises her tissue stores during periods of nutrient deprivation, in some cases until a maternal disease state develops (Holland and Odde 1992). These maternal metabolic and physiological adaptations allow variations in maternal nutrient intake to have only minor affects on birth weight of the calf in some cases (Holland and Odde 1992; Bell 2005). Rice (1994) reported that cows fed an energy-deficient diet prepartum carried heavier placentas than adequately fed dams, suggesting that placental size was increased to maintain the supply of maternal nutrients to the fetus. Furthermore, the fetus can utilise allantoic and amniotic fluid as a nutrient supply during periods of acute or moderate nutrient deprivation (Holland and Odde 1992).

Fetal growth follows an exponential growth curve, with the greatest absolute increases in fetal weight occurring in the third trimester (Ferrell *et al.* 1976; Prior and Laster 1979; Corah 1987), and the greatest relative increases occurring in early pregnancy (Robinson 1977). Much of the birth weight research in cattle has focused on the effects of late-pregnancy feeding; however, in recent years, positive associations between the level of feeding in early pregnancy and the incidence of dystocia in heifers have been made anecdotally by New Zealand veterinarian practitioners, indicating that nutrition in early gestation may have the potential to manipulate birth weight, possibly through effects on the development of the placenta. Placental size and nutrient transfer capacity play a central role in determining fetal growth and consequently birth weight in sheep (Wallace *et al.* 1999) and birth weight has been related to placental weight in cattle (Echternkamp 1993). Differences in birth weight of the calf and calving performance have been observed consistently among cattle calving in different seasons, or grazed on different land types (Lowman 1979). These differences are likely to be at least partly caused by nutritional differences.

Early pregnancy

Sawyer *et al.* (1991) found a negative relationship with birth weight of the calf for both condition of the dam and liveweight change at the beginning of joining. Heifers fed to achieve moderate growth from their weaning to joining were heavier at calving but produced calves of the same birth weight as heifers fed to a achieve slow growth from their weaning to joining, and moderately grown heifers experienced less dystocia (Barker *et al.* 1985). Conversely, Cooper *et al.* (1998) reported no effect on birth weight of calves of feeding 15-month-old heifers to gain 0.60 kg/day or 0.10 kg/day for the first 140 days of pregnancy. Bellows *et al.* (1971b) reported a positive correlation between liveweight gain of the heifer from the end of joining until mid-pregnancy and birth weight of the calf for Hereford but not for Angus heifers, and there was no affect on assistance at calving for either breed. The effect of nutrition in early- to mid-pregnancy on birth weight was examined by Lowman (1979), who fed mature cows fed at 90, 125 or 175% of maintenance for the first five months of pregnancy. The cows on the lesser feed allowances were then preferentially fed so that all cows reached similar live weights at calving. The calves of cows fed 90% of maintenance for the first five months of pregnancy were 1.37 kg lighter than the calves from the cows on the high feed intake (Lowman 1979).

Increased fetal and placental weights were observed in ewes fed 1.5 times maintenance compared with maintenance or 0.5 times maintenance from Day 21 to 101 of pregnancy (Cooper *et al.* 1998). Feeding adolescent ewes (hoggets) at high, compared with maintenance, levels in the first trimester of pregnancy resulted in placentas with fewer cotyledons and a greater fetal:placental weight ratio at term, although birth weight of lambs was not affected by first-trimester feeding level (Wallace *et al.* 1999). Whilst early maternal nutrient restriction (up to Day 90 of pregnancy) can result in reduced embryo weight (Parr *et al.* 1986), often fetuses were able to increase their growth rate later in gestation to reach birth weight comparable with that of the lambs born to ewes fed a normal diet. In contrast, Everitt (1967) found that birth weight of lambs was reduced by nutrient restriction in the first 90 days of pregnancy, regardless of nutritional treatment for the remainder of pregnancy. These results are indicative of potential responses that may be observed in cattle.

Maternal nutrition during early pregnancy may have implications for embryo survival (Mackenzie and Edey 1975). Although Parr *et al.* (1982) found that there were no differences in embryo survival to Day 21 of gestation between ewes fed 25% of their maintenance requirement and those fed 100% of their maintenance requirement for the first 21 days after mating, the embryos of the ewes on the low feeding level were smaller than those of the ewes fed to requirement and showed retarded development. The absolute nutrient demand of the fetus is very low in early gestation, suggesting that growth retardation caused by maternal undernutrition in early pregnancy may not have been due to an inadequate supply of nutrients available to the fetus, but rather was the result of endocrine changes in the dam, initiated by maternal undernutrition (Robinson 1977).

A noteworthy feature of the literature was the lack of clear information pertaining to heifers in relation to early pregnancy feeding and its effects on fetal and placental growth and development.

Mid pregnancy

Few studies have examined the effects of mid-pregnancy feeding on birth weight of calves. Khadem *et al.* (1996) fed heifers to gain 0.72 kg per day or 0.16 kg per day from day 114 to day 214 of pregnancy, but observed no significant differences in birth weight of the calves or dystocia score, despite the heifers with low liveweight gain having lesser pre- and post-calving live weights. Weaning weight of the calf was also not affected by mid-pregnancy nutrition within these limits (Khadem *et al.* 1996). Similarly, there were no differences in fetal weight from day 87 to day 277 of gestation in heifers fed for low, medium or high liveweight gain starting on Day 35 to 42 of pregnancy until slaughter (Prior and Laster 1979). Although elevated mid-pregnancy nutrition was associated with an increase in birth weight of the calf in mature Angus cows, the cows on high feeding were also heavier at calving (Hight 1966). These studies suggest there is little to be gained by manipulating heifer nutrition in mid-pregnancy.

Late pregnancy

Undernutrition in pregnancy has been reported to have more effect on the birth weight of calves born to heifers than on the birth weight of calves born to mature cows, probably because there was more competition between energy demands for pregnancy and growth (Drennan 1979; Meijering 1984).

Heifers fed on high planes of nutrition in late pregnancy produced calves with greater birth weight than heifers fed on lower planes of nutrition (Rice and Wiltbank 1972; Laster 1974; Drennan 1979; Kroker and Cummins 1979; Axelsen *et al.* 1981; Wiltbank and Remmenga 1982; Nicoll *et al.* 1984; Pleasants and Barton 1992; Spitzer *et al.* 1995), although Bellows *et al.* (1982) reported no effect of late-pregnancy feeding on either birth weight of calves or incidence of dystocia. Similarly, Anderson *et al.* (1981) and Pleasants and Barton (1987) reported that the pattern of live weight gain over the last trimester did not affect birth weight of calves.

The consequences of the greater feed intake and increased birth weights for the incidence of dystocia were inconsistent, having no effect in many cases (Hodge and Stokoe 1974; Laster 1974; Kroker and Cummins 1979; Axelsen *et al.* 1981; Wiltbank and Remmenga 1982; Spitzer *et al.* 1995). In some studies, the better-fed heifers experienced more dystocia (Hodge and Stokoe 1974; Drennan 1979; Wiltbank and Remmenga 1982; Pleasants and Barton 1992), whilst in other studies, the incidence of dystocia was reduced in the better-fed heifers relative to the heifers on the lesser feed intake (Rice and Wiltbank 1972; Hodge *et al.* 1976; Drennan 1979). The effects of nutrition in late pregnancy on dystocia may be confounded with effects on live weight or body condition score of heifers at calving (Drennan 1979; Lowman 1979) or possibly with feeding in early pregnancy and its potential influence on placental development. Table 1.6 details birth weight and incidence of dystocia from experiments examining the effects of feeding of heifers in late pregnancy.

Laster (1974) reported that the increased birth weight resulting from high feeding in late pregnancy was composed of soft tissue mass, because there were no differences between the groups for a range of body dimensions of calves, including shoulder width, hip width, chest depth and body length. Additionally, these measurements had no significant effect on dystocia once adjusted for birth weight (Laster 1974). Kroker and Cummins (1979) reported an effect of late-gestation nutrition on hip and length measurements of Friesian-cross-Hereford calves, and calves born to heifers fed to gain 0.75 kg per day had longer bodies and wider hips than calves born to heifers fed to lose 0.50 kg per day for the last three months of gestation. In Hereford heifers bred with Hereford bulls, hip width of calves was not significantly affected by nutritional treatment of the dams, but body length was affected in the same manner as for the Friesian-cross calves (Kroker and Cummins 1979). Incidence of dystocia was low for all treatments, and no relationship between body dimensions of calves and dystocia was identified (Kroker and Cummins 1979).

Kroker and Cummins (1979) also reported that there was a tendency for heifers on a low plane of nutrition for the final 12 weeks of pregnancy to have a longer parturition than heifers on a high plane of nutrition. Additionally, their calves took longer to stand and to suckle than calves born to heifers on a high plane of nutrition (Kroker and Cummins 1979). Similarly, Singh *et al.* (2003) found that cows fed at NRC standard for

Table 1.6. Effect of feeding level during the last 12 weeks of pregnancy on birth weight of the calf and incidence of dystocia (from Kroker and Cummins 1979).

Treatment	High	Medium	Low
Hereford heifers pregnant to Friesian bull (pre-treatment live weight 342 kg)			
n	20	20	20
Liveweight change (kg)	74.6^a	-9.5^b	-47.5^c
Birth weight of calves (kg)	32.5^a	28.6^b	24.6^c
Dystocia cases	3	1	5
Hereford heifers pregnant to Hereford bull (pre-treatment live weight 327 kg)			
n	19	19	18
Liveweight change (kg)	42.5^a	-11.8^b	-46.2^c
Birth weight of calves (kg)	27.3^a	24.9^b	21.9^c
Dystocia cases	0	2	1

$^{a, b, c}$ Values within rows with different superscripts differ at the $P<0.05$ level the last 60 days of pregnancy were lighter at calving, had longer parturitions and heavier placentas than cows fed at 20% above NRC standards for the last 60 days of pregnancy, although there was no difference in birth weight of the calves between the treatment groups. Undernutrition has been associated with slower progesterone clearance, and consequently may be a route by which undernutrition resulted in prolonged parturition (Rabiee *et al.* 2001).

Restricted feed intake in late pregnancy resulted in loss of body condition and had negative effects on lactation performance and metabolic health of the dam (Kroker and Cummins 1979; Lowman 1979; Bell 2005). Heifers kept on a low nutritional level for the last three months of pregnancy took longer to return to oestrus and to conceive than heifers fed at a high nutritional level (Bellows *et al.* 1982). Therefore, underfeeding during late pregnancy in an attempt to limit birth weight of the calf also resulted in compromised performance of the dam.

Other environmental effects

Other environmental factors also influenced birth weight and dystocia, independent of their effect on nutrition. A 1°F decrease in average winter temperature was associated with a one pound increase in birth weight and a 2.6% increase in incidence of dystocia in two-year-old heifers (Bell 2005). Conversely, chronic heat stress in mid-late pregnancy had negative effects on placental growth and uterine and umbilical blood flows, and led to decreased birth weight in sheep (Bell 2005). High temperatures also affected uterine blood flow in cows and reduced placental mass, resulting in lighter calves at birth (Holland and Odde 1992; Rice 1994). Season has also been shown to influence birth weight; however, effects were variable and inconsistent, and may actually have been temperature effects (Holland and Odde 1992). Johansen and Berger (2003) found that calves born in winter had a 15% greater risk of dystocia than calves born in summer.

Summary and implications

Methods of reducing dystocia, particularly in heifers, are of interest to farmers, because successfully reducing the incidence of dystocia in heifers would enable more heifers to be bred at 15 months of age, and reduce calf losses in herds currently calving heifers at two years of age, allowing more calves to be produced each year. Dystocia is one of the reasons some farmers are not breeding heifers at 15 months of age. Control of birth weight of calves relative to live weight of the heifers is likely to effectively minimise dystocia in heifers. One way to manipulate birth weight is through sire selection but this will only partially resolve the issue. Restricted feeding of heifers in the last trimester of pregnancy has variable effects on dystocia, and has undesirable effects on the lactation and rebreeding performance of the heifers. The role of liveweight gain of heifers during early pregnancy has not been thoroughly examined.

Research objectives

The aims of this thesis were to:

- Quantify the relative profitability of calving heifers at two compared with three years of age in a simulated beef cattle system.
- Quantify the impact of variation in the incidence of assistance at calving on the profitability of calving heifers at two years of age.
- Quantify the proportion of farmers calving heifers at two or three years of age in New Zealand in 2006, and establish the importance of various factors affecting the choice of calving age.
- Identify strategies used to manage dystocia in primiparous heifers, and to ascertain the outcomes of assistance at parturition for two-year-old heifers in industry.
- Determine whether liveweight gain of 15-month-old heifers up to 10 days prior to conception and in the first trimester of pregnancy affects the birth weight of calves.
- Investigate the impact of maternal liveweight gain up to 10 days prior to conception and in the first trimester of pregnancy on the live weight and milk intake of calves and the live weight and inter-calving interval of heifers.
- Examine the effects of variation in maternal liveweight gain for 21 days prior to insemination and for the first trimester of pregnancy on the conceptus at the end of the treatment period.
- Evaluate body dimensions of calves and maternal plasma oestrone sulphate concentration as potential contributors to the need for assistance at parturition in two-year-old heifers.

CHAPTER 2

Profitability of calving heifers first at two compared with three years of age and the effect of incidence of assistance at parturition on the profitability of calving heifers at two years of age

Abstract

There is potential to increase the profitability of beef breeding cows in New Zealand by calving heifers for the first time at two instead of three years of age, however, calving at this earlier age is often associated with an increase in assistance at calving. This study used a simulated farm system within the Grazing Systems Model (Ridler *et al.* 2001) to estimate the profitability of calving heifers at two years of age with various incidences of assistance at calving. Annual profit from the beef cattle herd was greater for primiparous two-year-old heifers than for three-year-old primiparous heifers when the incidence of assisted calving in two-year-old heifers was less than 89.4%. Replacement rate increased with increased assistance at parturition. These results indicated that a considerable gain in profitability could be made by calving heifers for the first time at two instead of three years of age, and further gains could be made in herds already calving heifers at two years of age by reducing the incidence of assistance at calving.

Introduction

Calving heifers for the first time at two instead of the traditional three years of age requires greater inputs to the beef cattle production system, particularly of feed and labour; however, it also has the potential to greatly increase the productivity of the breeding cow herd, in terms of number of calves weaned annually per breeding female. Calving two-year-old heifers is likely to have multifaceted effects on production – increasing number of calves weaned whilst decreasing average weight of calves weaned in the short term, as well as potential long-term implications for subsequent performance and longevity of cows.

The profitability of calving heifers at two years of age depends on the relative impacts on each of these performance measures. Particularly, dystocia (and, therefore, assistance at calving) may play an important role as this affects the survival of heifers and calves during the neonatal period (Meijering 1984; Rice 1994; Arthur *et al.* 2000; Larson and Tyler 2005). Incidence of assisted calving shows considerable variation amongst herds, and is particularly prevalent in primiparous two-year-old heifers.

The aims of this simulation were to quantify the relative profitability of calving heifers for the first time at two or at three years of age on a 100 ha hill country farm in the North Island of New Zealand, and to examine the effect on profitability of variation in the incidence of assistance at parturition for primiparous, two-year-old heifers.

Materials and methods

Simulation

A simulated production system was generated using the Grazing Systems Model (Ridler *et al.* 2001), which uses linear programming to find the optimal solution. Two scenarios were considered; namely, a beef cattle herd in which heifers calved for the first time at two years of age, and a herd in which heifers calved for the first time at three years of age. Within the scenario in which heifers were calved for the first time at two years of age, the incidence of assistance at calving was varied between 1.7% (incidence in three-year-old primiparous heifers) and 100%. The age structure of the herd was calculated for each simulation using Markov chains (Azzam *et al.* 1990; Cook and Russell 1993). Herd size was optimised within the model to suit the pasture available to the breeding cows, replacement heifers and the progeny to be sold. Data used to define some of the conditions of the model were drawn from surveys completed as part of this thesis (see Chapters 3 and 4).

Conditions

Cattle

Pregnancy rate to first joining at 15 months of age was 86% (Chapter 4). The same pregnancy rate was used for heifers joined with a bull for the first time at 27 months of age (Thomas *et al.* 2007). Base incidence of assisted calving was 7.0% for primiparous two-year-old heifers and 1.7% for primiparous three-year-old heifers (Chapter 3). As a result of assisted calving, 11% of assisted heifers were assumed to have died and a further 20% of assisted heifers were culled for having a dead calf; this equated to 31% mortality of calves born to assisted heifers (Chapter 4). Survival from first to second calving was reported to be 84% for heifers bred for the first time at 15 months of age at the base incidence of assistance at calving (Chapter 4), which implied a culling rate of 14% for failure to conceive and other reasons. The same culling rate as for primiparous two-year-old heifers was imposed on survival of primiparous three-year-old heifers to four years of age (Thomas *et al.* 2007).

Retention of cows within the herd from second calving till 10 years of age was adapted from Nunez-Dominguez *et al.* (1991), assuming cows were culled the first time they were non-pregnant, and scaled relative to the retention rate of primiparous heifers reported in Chapter 4. Culling of non-pregnant cows occurred in the last fortnight of August, and calving occurred in the first fortnight of September. The Grazing Systems Model did not allow the option of reducing the number of calves weaned to less than one per cow calved. To effectively impose a neonatal death rate, cows that had dead calves were 'culled' in the last fortnight of August to remove them and their calf from the herd. This change would not greatly impact the results of the model relative to what would have been achieved if the calving percentage was decreased and the cow culled shortly after calving.

Of the cows that left the herd each year, 17.2% were attributed to deaths and the remainder to culling (Thomas *et al.* 2007), except within the primiparous heifers (either two or three years of age), among which there were additional deaths to allow for increased assistance rates, as detailed previously. Losses of heifers between one and two years of age in herds with two-year-old primiparous heifers and between two and three years of age in herds with three-year-old primiparous heifers were all attributed to culling based on failure to conceive at first joining. No allowance was made for an effect of assistance at calving on rebreeding performance or days to calving, on the basis that heifers whose calf died as a result of dystocia were culled and evidence indicates no effect of assistance at calving on the rebreeding performance of the remaining cows (Laster *et al.* 1973; Johnston and Bunter 1996).

Milk yield throughout lactation and live weight of calf at weaning was assumed to be 86.8% of that of mixed-aged cows for primiparous two-year-old heifers, and 92.4% of that of mixed-aged cows for primiparous and multiparous three-year-old heifers (Carter and Cox 1973; Morris *et al.* 1993). Cows that were at least four years old at calving all achieved similar weight of calf weaned (Morris *et al.* 2006), and milk production of these cows was presumed to also be similar. Calves were weaned at 30 weeks of age, weighing 45% of mature cow live weight. Mature live weight of the cows was 450 kg. Heifers weighed 245 kg at one year of age, 350 kg at two years of age, 400 kg at three years of age and had reached mature size at four years of age, irrespective of age at first calving.

Pasture

The model assumed that 100 ha were available for the cow herd to graze. Monthly growth rates and metabolisable energy content of pasture and pasture utilisation data

(Table 2.1) were those reported for a central North Island sheep and beef cattle farm by Webby and Bywater (2007).

Table 2.1. Monthly growth rate, utilisation and metabolisable energy content of pasture (from Webby and Bywater 2007).

Month	Growth rate (kg DM/ha/day)	Utilisation (% DM)	Metabolisable energy content (MJ/kg DM)
July	8	95	11.0
August	15	95	11.4
September	30	85	11.3
October	40	80	11.3
November	45	75	11.4
December	40	70	11.6
January	35	70	10.2
February	32	70	10.4
March	15	75	10.4
April	25	75	10.8
May	18	85	11.0
June	8	90	11.0

Income and costs

Income from culled cows and prime and store progeny sold were derived from weekly beef schedules for 2004/05 (Anonymous 2004, 2005). The model determined the best time to sell the progeny using the market schedules input and the growth trajectory of the animals. Culled cows were sold on the date specified.

Animal health costs excluding anthelmintic treatment were limited to $4 per head at 10 weeks of age to cover the costs of tagging and castrating the calves and animals were drenched monthly from weaning to one year of age, and bi-monthly from one year of age until slaughter or first calving. From calving, cows were drenched annually in July. For simplicity, all drenches were with Ivomec® injection at a dose rate of 1 ml per 50 kg and a cost of $1.75 per ml. The model was given the option to make silage (conserve pasture) at a cost of $0.15 per kg DM from October to December, which could be fed out at 85% utilisation and a cost of $0.10 per kg DM. Cost to discard unused silage was also set at $0.10 per kg DM.

Costs associated with assisted calving were veterinary assistance for 6% of assisted heifers (Chapter 4) at a cost of $236 per heifer assisted (L. England, Massey University Farm Services Veterinary Teaching Hospital, personal communication, 29th August

2008). The other cost included was staff labour (2 hours at $20 per hour) for all assisted heifers. An additional one hour of labour was added for heifers assisted by a veterinarian. Costs of daily observation of heifers were not included as this was likely to occur independent of the likelihood of dystocia to some extent and would occur for both two- and three-year-old, primiparous heifers.

The model generated a value for profit based on income from sale of stock less the tagging, castration, drench and silage costs detailed. From this value, cost of pasture grown ($0.07 per kg DM) and cost of assistance at parturition were subtracted to give a final value for profit.

Variable parameters

The factor of interest in this simulation was the impact of increased assistance at calving on the relative profitability of calving heifers for the first time at two instead of three years of age. Therefore, incidence of assistance at calving in primiparous two-year-old heifers was varied from equivalent to that of primiparous three-year-old heifers, to 100%.

Results

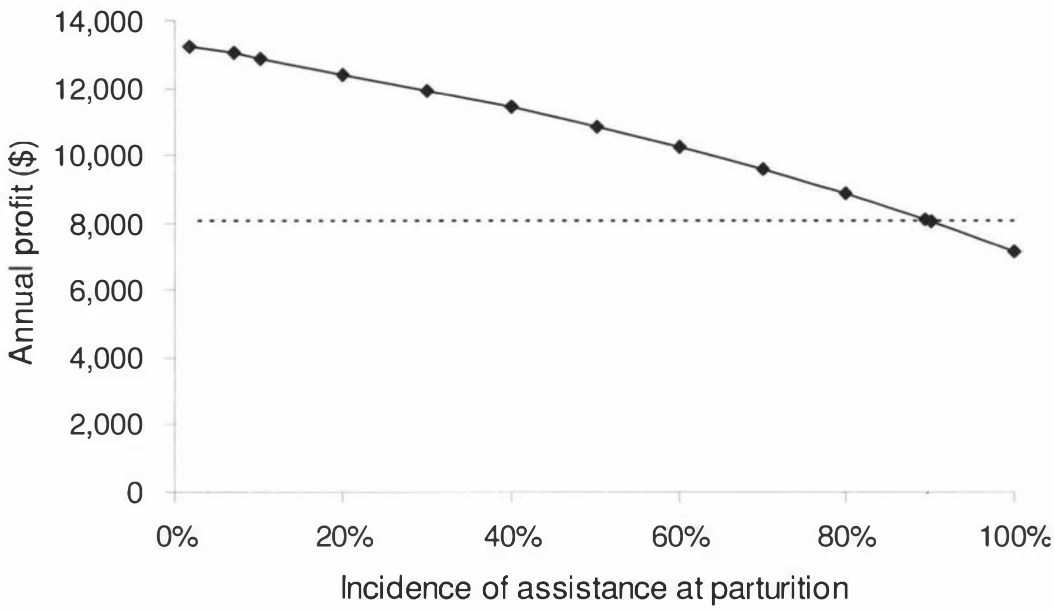
The age structures generated in response to the conditions imposed are detailed in Table 2.2. As incidence of assistance at calving of two-year-old heifers increased, the percentage of animals in the one- and two-year-old age groups increased to allow for the increased rate of culling and mortality in the primiparous two-year-old heifers. At low incidences of assistance at calving, this increased percentage of young heifers was achieved by increasing number of young heifers with little effect on the total number of females calving, but as incidence of assistance at calving increased, the number of calving females also increased. The total herd size and the number of calving females were considerably greater for herds in which heifers calved at two compared with the herd with three-year-old primiparous heifers.

At an incidence of assistance at calving of 1.7%, calving heifers for the first time at two years of age was considerably more profitable than calving heifers for the first time at three years of age (Figure 2.1). The relative profitability of calving heifers at two years of age decreased with increasing incidence of assistance at calving, but remained more profitable than calving heifers at three years of age until the incidence reached 89.4%.

Table 2.2. Age structure (percent of females of each age), total number of breeding females, number of primiparous heifers and total number of calving females in simulated herds with either two- or three-year-old primiparous heifers and variable incidence of assistance at parturition in two-year-old, primiparous heifers. Herd size was optimised to allow finishing of non-replacement progeny on a 100 ha farm growing 9688 kg DM/ha annually. Females were culled for failing to rear a calf or if diagnosed non-pregnant after any breeding period. Remaining cows were culled at 10 years of age. Values in bold indicate primiparous heifers.

Herd	Assistance %	Age (years)										Number of females		
		1	2	3	4	5	6	7	8	9	10	Total	First calf	Total calved
3	1.7	14.4	14.2	**12.3**	10.5	9.9	9.4	8.8	8.4	6.7	5.4	180	22	129
2	1.7	17.3	**14.9**	12.8	11.6	9.8	9.0	8.0	6.3	5.5	4.7	177	26	146
2	7	17.5	**15.1**	12.7	11.5	9.8	8.9	8.0	6.3	5.5	4.7	179	27	147
2	10	17.7	**15.3**	12.7	11.4	9.7	8.9	7.9	6.3	5.5	4.7	179	27	147
2	20	18.1	**15.6**	12.5	11.3	9.6	8.8	7.8	6.2	5.4	4.6	181	28	148
2	30	18.6	**16.1**	12.3	11.1	9.5	8.7	7.7	6.1	5.3	4.5	179	29	146
2	40	19.1	**16.5**	12.1	11.0	9.4	8.6	7.6	6.0	5.2	4.5	181	30	147
2	50	19.6	**17.0**	12.0	10.8	9.2	8.4	7.5	5.9	5.2	4.4	185	31	148
2	60	20.2	**17.4**	11.8	10.6	9.1	8.3	7.4	5.8	5.1	4.3	182	32	145
2	70	20.8	**17.9**	11.6	10.4	8.9	8.1	7.3	5.7	5.0	4.3	185	33	147
2	80	21.4	**18.5**	11.3	10.2	8.7	8.0	7.1	5.6	4.9	4.2	189	35	149
2	89	22.1	**19.0**	11.1	10.0	8.6	7.8	7.0	5.5	4.8	4.1	193	37	150
2	90	22.1	**19.1**	11.1	10.0	8.5	7.8	7.0	5.5	4.8	4.1	193	37	150
2	100	22.8	**19.7**	10.8	9.8	8.4	7.6	6.8	5.4	4.7	4.0	198	39	153

Figure 2.1. Profitability of simulated herds with two-year-old primiparous heifers in which incidence of assistance at parturition varied from 1.7–100%. For comparison, the dotted line shows the profitability of a herd with three-year-old primiparous heifers and 1.7% assistance at parturition.



Discussion

Calving heifers at two years of age was more profitable than calving heifers first at three years of age (incidence of assistance at parturition 1.7%), for incidence of assistance at parturition in two-year-old heifers ranging up to 89.4%. Evidently even a low proportion of surviving calves born to two-year-old heifers present an opportunity to generate income that would not have been generated had the heifers calved for the first time at three years of age. This is in agreement with previous work highlighting increased lifetime productivity per cow in herds in which heifers calved at two years of age (Bernard *et al.* 1973).

Profitability decreased with increasing incidence of assistance at parturition, as expected. The impact of requiring assistance was two-fold; firstly, assistance at parturition directly affected the costs of the operation by requiring labour and veterinary attention for the heifers involved, and secondly, reducing income through mortality of calves and heifers. In spite of this reduced profitability, calving two-year-old heifers remained more profitable than calving heifers for the first time at three years of age until incidence of assistance at parturition was 89.4%. This is in agreement with the findings of a survey of beef cattle farmers, in which it was evident that the majority of farmers (with either two- or three-year-old, primiparous heifers) recognised the greater profitability of calving heifers at two years of age (see Chapter 3).

Herd size increased with increasing assistance at parturition because fewer calves were reared per cow, so less pasture was consumed by the progeny, enabling more cows to be grazed. Additionally, the greater proportion of replacement heifers in the herd reduced the mean feed requirement per female, because the young animals had less feed requirement than mature cows. The number of calving females was less for herds with three-year-old primiparous heifers than for herds with two-year-old primiparous heifers because non-calving, replacement heifers had to be accommodated on the farm for an additional year.

There is conflicting evidence as to whether calving heifers at two years of age affects the live weight of the heifers. Bernard and Lalande (1967) reported a negative impact of calving at two years of age on the live weight of the heifer that lasted until 5.5 years of age, whereas Pinney *et al.* (1972) observed no difference in live weight. In contrast, McMillan and McCall (1991) suggested that heifers that calved first at three years of age would be lighter until two years of age because there was no need for them to reach puberty by 15 months of age and management would be likely to reflect this. Similar live weights regardless of age at first calving were assumed in this simulation because a reduction in live weight of heifers calved at two years of age would further increase the efficiency and profitability of this scenario and evidence for a reduction in live weight is not conclusive. Therefore, the use of similar live weights generated a conservative estimate of the increased profitability of calving heifers at two instead of three years of age. If heifers calved at two years of age are lighter at maturity, they would have less feed requirements for maintenance during their lifetime.

Farmers that currently calve heifers for the first time at three years of age have cited concern about the rebreeding performance of primiparous two-year-olds as an important factor influencing their decision (Chapter 3). Evidence from studies in beef-breed heifers indicates there was no difference between intercalving interval and days to calving among assisted or non-assisted heifers (Johnston and Bunter 1996), however, this study did not consider heifers that were culled prior to their second joining, which would have included the majority of heifers whose calf died as a result of dystocia. Therefore, this comparison between assisted and non-assisted heifers excluded many of the heifers that experienced the most severe cases of dystocia, potentially creating biased results. Yet it is the norm on many beef cattle farms that heifers that have a dead calf are culled (Chapter 4) and so such comparisons are indicative of the on-farm situation.

In this simulation, increased assistance at calving reduced the profitability of calving two-year-old heifers, but within the realistic range of values for assistance at parturition (perhaps 1–50%), calving primiparous two-year-old heifers was considerably more profitable than calving primiparous three-year-old heifers. It would be realistic to presume that in herds in which two-year-old primiparous heifers had an extremely high rate of assistance at parturition, if the heifers were instead calved for the first time at three years of age, they would still experience a greater than average incidence of assistance at parturition. Many of the factors contributing to dystocia in two-year-old heifers in the herd would still be present to affect primiparous three-year-old heifers in the same herd, although the heifers are likely to be heavier at three than at two years of age. Thus, comparisons between two-year-old primiparous heifers with a high incidence of assistance at parturition and three-year-old primiparous heifers with a low incidence of assistance at parturition are likely to be biased in favour of three-year-old primiparous heifers. Therefore, the incidence of assistance at parturition at which calving heifers first at three is more profitable than calving heifers first at two may be even greater than that reported here.

In light of the increased profitability of two-year-old compared with three-year-old primiparous heifers reported here, it seems surprising that 21% of respondents to a survey of beef cattle farmers in New Zealand reported that they had only three-year-old primiparous heifers (Chapter 3). This indicates that this simulation may under-value the costs of calving two-year-old heifers on some farms. For example, to best match feed demand of the herd with pasture availability, heifers are generally calved in spring, coinciding with the lambing period on many properties. If the farm staff were already spending many hours supervising ewes and lambs at lambing, they may not be available to supervise and assist heifers at calving. Such supervision and assistance of heifers may then either require an additional labour unit to be employed, which would make the cost of this labour greatly in excess of the hourly rate used in this simulation; or the assistance of the heifers would come at the expense of supervision of lambing ewes, so that the increased income from the cattle would be offset against decreased income from the ewe flock if ewes and/or lambs died as a result of the decreased supervision.

Alternatively, some properties, particularly those with extremely rough terrain, may not have suitable paddocks to allow observation of heifers at calving, or to make it feasible to move heifers in difficulty to an area in which they can be restrained for assistance. If heifers that experienced dystocia were not assisted, the impact of dystocia could be considerably greater than the 31% of dead calves and 11% of dead heifers used as the basis of this simulation. Previous reports have indicated that survival of both heifers and calves is less in herds in which appropriate supervision and assistance is not provided than in herds where assistance is administered if necessary (Hodge *et al.* 1982).

It is in cases such as these two aforementioned scenarios that a reduction in incidence of dystocia and, therefore, the need for supervision and assistance of two-year-old primiparous heifers would have the greatest impact on the profitability of the beef herd. These results indicate that reducing assistance at parturition from 40% to 1.7% in a herd already calving heifers at two years of age would increase profitability by $1.36 per t DM or 11% per annum (for a herd with 968.8 t DM pasture available annually), whereas reducing dystocia to such an extent that it became possible for a herd previously calving heifers at three years of age (and achieving 1.7% assistance) to instead calve heifers at two years of age with the same incidence of assistance at parturition would see profit increase by $5.28 per t DM or 63% per annum under the same pasture constraints.

Conclusion

This simulation indicated that it is more profitable to calve heifers at two than at three years of age, and that the relative advantage of two-year-old calving was eroded by an elevated incidence of assistance at parturition. Methods for reducing the incidence of dystocia (and assistance at parturition) in two-year-old heifers would be particularly beneficial if they enabled farmers currently calving their heifers for the first time at three years of age to instead calve their heifers at two years of age.

Implications

The results of this simulation indicate that it is considerably more profitable to calve heifers at two than at three years of age in most cases. In spite of this, Thomas *et al.* (2007) reported that only 61% of farmers in Canterbury, New Zealand, calved heifers at two years of age. Further investigation of reasons farmers choose to calve heifers at two or at three years of age is warranted.

CHAPTER 3

A survey of beef cattle farmers in New Zealand, examining management practices for primiparous beef breeding heifers

Publications arising from this chapter:

Hickson RE, Anderson WJ, Kenyon PR, Lopez-Villalobos N, Morris ST. A survey of beef cattle farmers in New Zealand, examining management practices of primiparous breeding heifers *New Zealand Veterinary Journal* 56, 176-83, 2008

Abstract

The aim of this study was to obtain an estimate of the incidence of assistance at parturition in primiparous beef heifers and the prevalence of breeding 15-month-old heifers in New Zealand in 2006, and to identify factors contributing to farmers' decisions regarding breeding strategies for heifers using a survey of beef cattle farmers. A questionnaire was sent out to farmers in a Massey University database and to members of selected breed societies, as well as published in an industry newspaper; 331 valid responses were received. Information was gathered on the age and number of primiparous heifers, number of heifers assisted, and the importance of various reasons for and against breeding heifers at 15 months of age. Respondents also outlined the criteria used for selecting bulls to breed with heifers, and the strategies used to manage dystocia in primiparous heifers. Sixty-five percent [95% CI 58–71%] of respondents had only two-year-old primiparous heifers in 2006, whilst a further 11% [8–16%] had some two- and some three-year-old primiparous heifers. The mean incidence of assisted calving was 7.0% [6.4–7.5%] for two-year-old primiparous heifers and 1.7% [1.2–2.2%] for three-year-old primiparous heifers. The incidence of assistance at calving within individual herds ranged from 0 to 100% for two-year-old heifers. Respondents with bull-breeding herds most commonly observed their primiparous two-year-old heifers twice daily, whilst respondents with commercial herds most commonly observed them once daily during calving. The most important reason for breeding heifers at 15 months of age was "increased profit", whereas the most important reason for not breeding them at that age was "concern about rebreeding performance of two-year-old heifers". Estimated breeding value (EBV) for birth weight was the factor considered most frequently when selecting bulls to breed with maiden heifers and selection of an appropriate bull was the most common strategy used to manage dystocia in two-year-old beef heifers. This survey indicated that many farmers calved beef heifers at two years of age, but concern regarding the impact of calving at two years of age on the subsequent performance of heifers was deterring other farmers from implementing the practice.

Introduction

Traditional beef cattle farming systems in New Zealand involved calving heifers for the first time at three years of age, yet calving heifers at two years of age is the norm in the dairy industry (Bryant *et al.* 2004). Most beef heifers have reached puberty by 15 months of age and could be bred to calve first at two years of age (Morris *et al.* 1986a). Breeding heifers at 15 instead of 27 months of age, to calve for the first time at two compared with three years of age, increased the efficiency of the beef breeding herd (McMillan and McCall 1991). The Agricultural Production Census of 2002 indicated that only 30% of beef heifers were bred at 15 months of age in that year (Anonymous 2003), however, that survey made no distinction between non-pregnant rising-2-year-old heifers that were kept as finishing cattle and would never be bred, and non-pregnant rising-2-year-old heifers that would be bred at 27 months of age. The inclusion of finishing heifers as non-pregnant rising-2-year-old heifers in this calculation reduced the apparent proportion of heifers bred at 15 months of age relative to the true proportion in which only heifers intended to be farmed as breeding cattle should have been considered.

Arguments in favour of breeding 15-month-old heifers generally concern economics, whereas arguments against tend to focus on the impact of calving at two years of age on the lifetime performance of the heifers and on other livestock on the farm. An increased incidence of dystocia in two-year-old compared with three-year-old primiparous heifers has also been cited as a reason for not breeding heifers at 15 months of age (Carter and Cox 1973; Hanly and Mossman 1977).

Various regional surveys have been carried out in the past to ascertain the percentage of farmers calving heifers at different ages, as well as various other parameters (Hanly and Mossman 1977; Parminter *et al.* 1993; Thomas *et al.* 2007). The regional nature of these surveys, as well as the considerable time lapse between surveys limits their usefulness in quantifying the national situation, or identifying regions in which there is a need for greater dissemination of research findings and aspects of production that require increased research focus.

The aims of this research were to quantify, via a survey of beef breeding cattle farmers, the prevalence of breeding heifers at 15 months of age, the incidence of assistance at parturition, and the perception and management of dystocia in primiparous heifers in 2006, as well as identify factors encouraging or deterring farmers from breeding heifers at 15 months of age. Criteria considered when selecting bulls to join with maiden heifers were also examined.

Materials and methods

Survey

Participants

A questionnaire was printed in the January 2007 issue of the northern *Country-Wide* newspaper (Country-Wide Publications Limited, Fielding, NZ) and the February 2007 issue of the southern *Country-Wide* newspaper, accompanied by an article about a Meat and Wool New Zealand- and Massey University-funded research project examining assisted parturition in two-year-old primiparous heifers. The questionnaire was reprinted in the March 2007 issue of the northern *Country-Wide* newspaper, without an accompanying story. The northern edition of *Country-Wide* newspaper was delivered to 59,000 rural mail-boxes in the North Island of New Zealand, and the southern edition was delivered to 26,000 rural mail-boxes in the South Island of New Zealand (T. Leggett, Editor, Country-Wide Publications, personal communication). Questionnaires were also distributed with breed society newsletters to members of the New Zealand Simmental (n=160), Hereford (n=330) and Angus (n=215) breed societies. A direct mail-out to 402 farmers on a fertility database collected and managed by Associate Professor Cord Heuer (EpiCentre, Institute of Veterinary, Animal and Biomedical Sciences, Massey University) and funded by Meat and Wool New Zealand was also carried out. Questionnaires were also promoted at the Central District Field Days and Beef Breeding Cow Focus Farm field days in Gisborne, Northland and Southland. Responses were accepted until 31 May 2007.

Questionnaire

The questionnaire was divided into three sections. The first section was completed by respondents with two-year-old primiparous heifers; the second section was completed by respondents with three-year-old primiparous heifers; and the third section was completed by all respondents. Respondents with some two-year-old and some three-year-old primiparous heifers were asked to complete all three sections, and those whose primiparous heifers were neither two nor three years old completed only the third section. There were a total of 29 questions in the questionnaire, which had been pre-tested in a pilot survey of 22 farmers and post-graduate students at Massey University.

The section for respondents with two-year-old primiparous heifers asked them to rate each of a list of reasons for breeding heifers at 15 months of age on a scale of 1 to 5 (1 = not important, 5 = very important). Respondents were asked how they selected heifers to be joined with a bull at 15 months of age, and how they selected bulls to join with heifers; for these questions a list of options was presented, and respondents were able to select multiple options. Respondents also specified how many two-year-old heifers calved and how many were assisted at parturition in 2006. They were asked to rate dystocia as a problem on a scale of 1 to 5 (1 = not a problem, 5 = a major problem), and to specify the frequency with which they observed their heifers during calving. Respondents were asked to identify strategies that they had used to manage calving difficulty in 2006; for this question respondents were presented with a list of options to choose from and they were asked to specify "other methods" they had used.

The section for respondents with three-year-old primiparous heifers asked them to detail whether the heifers had been joined with a bull at 15 months of age, and to rate reasons for not joining heifers with a bull at 15 months of age on a scale of 1 to 5 (1 = not important, 5 = very important). Similar questions to those asked of respondents with two-year-old primiparous heifers were also included, which detailed the number of three-year-old heifers calving for the first time and the number assisted at parturition, criteria used to select bulls for joining with heifers, and strategies for managing dystocia in heifers. They were also asked whether they had bred heifers at 15 months of age in the past, and whether they would change their policy to breed heifers at 15 months of age if dystocia could be eliminated in these heifers.

The final section asked for farm information, including location, effective land area, herd size, breed of female breeding cattle, and whether farmers had commercial cattle or a bull-breeding herd.

Statistical analysis

Data management

Respondents were classified for analysis purposes based on type of herd: those with cattle used only for bull breeding (bull-breeding herds), those with commercial cattle only (commercial herds), and those with some bull-breeding and some commercial cattle (mixed herds); and based on age of primiparous heifers: those with two-year-old primiparous heifers only, those with three-year-old primiparous heifers only, those with some two-year-old and some three-year-old primiparous heifers, and those with 2.5-year-old primiparous heifers (bred at 18–21 months of age).

In some cases, respondents had completed a single questionnaire for more than one herd, in which case the responses that varied among herds were deleted from the record and new records were created that contained this information. For example, a respondent indicated that they had a mixed herd and checked heifers in the bull-breeding herd twice daily at calving and never checked commercial heifers; the frequency of supervision was left blank in the original record and two new records were created that each had age of primiparous heifers, frequency of supervision, and type of cattle (bull-breeding or commercial) as the only variables included.

Statistical analyses

Statistical analyses were carried out using the Statistical Analysis System (SAS version 9.1, SAS Institute Inc., Cary, NC, USA, 2003). The descriptors of respondents, mean and range of percentage and number of heifers assisted (Table 3.3), and mean ratings of reasons for and against breeding heifers at 15 months of age were calculated using the MEANS procedure. Percentage values, least squares means and exact 95% CI for all other results were calculated using the GENMOD procedure with a binomial distribution and a logit transformation. Where multiple comparisons were made, a Bonferroni adjustment was used. Probabilities and odds ratios were calculated using the LOGISTIC procedure for logistic regression. Differences in proportions of respondents with two-year-old primiparous heifers among regions were identified using the CONTRAST statement in the LOGISTIC procedure.

Results

Respondents

A total of 331 valid responses (questionnaires) was received, from farmers responsible for 15,985 primiparous two- or three-year-old beef heifers. Thirty-six percent of responses came from the direct mail-out to beef cattle farmers; 30.5% from the questionnaires printed in *Country-Wide*; 28% from breed-society mail-outs to members of the Simmental, Hereford, and Angus breed societies; and 5.5% from promotion of the questionnaire at industry field days.

The distribution of two- and three-year-old primiparous heifers among regions within the survey respondents was similar to the distribution of beef breeding cattle across New Zealand (Table 3.1), although Northland and Otago were under-represented, and Gisborne and Hawke's Bay were over-represented based on number of primiparous heifers. It appears that the sample of farmers who responded to the survey provided a reasonable representation of the national distribution of herds, although seeking respondents through breed societies resulted in a greater than representative number of responses from bull breeders. Fourteen percent of respondents (46/331) had bull-breeding herds, 25% (83/331) had mixed herds and 61% (202/331) had commercial herds, compared with 7% of all beef cattle herds identified as bull-breeding herds in 2007 (Morris and Archer 2007).

Angus and Hereford were the most common breeds; 190/331 (57%) of respondents farmed Angus or Angus crossbred cattle and 175/331 (53%) farmed Hereford or Hereford crossbred cattle. Other British breeds or crossbreds were present on 28/331 (8%) of respondents' farms. Eleven percent of respondents (36/331) farmed Simmental or Simmental crossbred cattle, whilst 20/331 (6%) of respondents had Charolais or Charolais crossbred cattle. Other continental breeds and crossbreds were present on

Table 3.1. Distribution of primiparous heifers of respondents to a survey of beef breeding cattle farmers in New Zealand by region, compared with distribution of breeding cows nationally.

Region	% of respondents' two- and three-year-old primiparous heifers	% of total breeding cows in New Zealand (Anonymous 2003)
North Island		
Northland	5	12
Waikato	3	5
Bay of Plenty	3	5
King Country	8	9
Manawatu/Taranaki	12	11
Gisborne	16	9
Hawke's Bay	18	12
Wairarapa	10	8
South Island		
Nelson/Marlborough	3	4
Canterbury/West Coast	13	13
Otago	3	7
Southland	5	6

33/331 (10%) of respondents' farms, 7/331 (2%) reported composite breeds, and 43/331 (13%) had crossbred dairy-beef cattle. The median effective land area of farms was 485 (range 4–18,000) ha, and median herd size (number of primiparous heifers plus number of mixed-age cows wintered) was 164 (range 3–3,700) cattle.

Age of primiparous heifers in 2006

The majority (65% [58–71%]) of respondents in this survey had two-year-old primiparous heifers. A further 11% [8–16%] had some two-year-old and some three-year-old primiparous heifers, 21% [16–27%] had three-year-old primiparous heifers, and 3% [1–6%] had 2.5-year-old primiparous heifers. There was some regional variation in age of primiparous heifers. Respondents from the East Coast of the North Island (Gisborne, Hawke's Bay, Wairarapa) were less likely to have only two-year-old primiparous heifers and more likely to have only three-year-old primiparous heifers than respondents from the rest of the North Island ($P<0.01$). Similarly, respondents from the South Island were more likely to have only two-year-old and less likely to have only three-year-old or both two- and three-year-old primiparous heifers than respondents from the North Island ($P<0.05$). These statistics were adjusted for type of herd. Herd size and effective land area did not affect the likelihood of respondents breeding heifers at 15 months of age, but for every 1 cow/ha increase in breeding-cow stocking rate (calculated as $\frac{\text{herd size}}{\text{effective land area}}$), the likelihood (odds ratio) of breeding some or all heifers at 15 months of age increased by 4.4 times [1.4–14.3 times].

Seventy-one percent [71–72%] of all primiparous heifers accounted for in this survey calved at two years of age. This proportion was least in commercial herds (69% [68–70%]), intermediate in mixed herds (73% [71–75%]), and greatest at 77% [75–79%] in bull-breeding herds.

Factors affecting the decision to breed heifers at 15 months of age

Reasons for breeding heifers at 15 months of age

Respondents that had two-year-old primiparous heifers rated "increased profit" and "the unproductive period of the heifer is reduced" as the two most important reasons for breeding heifers at 15 months of age (Figure 3.1). Respondents that had commercial herds were 2.3 [1.3–4.1] times more likely, and respondents with mixed herds 2.6 [1.1–5.9] times more likely, than respondents that had bull-breeding herds to rate "increased

Figure 3.1. Ratings of reasons for breeding heifers at 15 months of age. Scale: 1=not important □, 2 ▧, 3 ▨, 4 ▩, 5=very important ■; NR=no response □. Bars represent the percentage of all respondents to a survey of beef breeding cattle farmers in New Zealand that had two-year-old primiparous heifers in 2006 that selected each rating, or did not respond. The mean rating for each reason is in brackets ('NR' responses were excluded from the mean). Possible reasons presented were:

A=Increased profit

B=The unproductive period of the heifers is reduced

C=More calves per cow over her lifetime

D=Increased rate of genetic gain

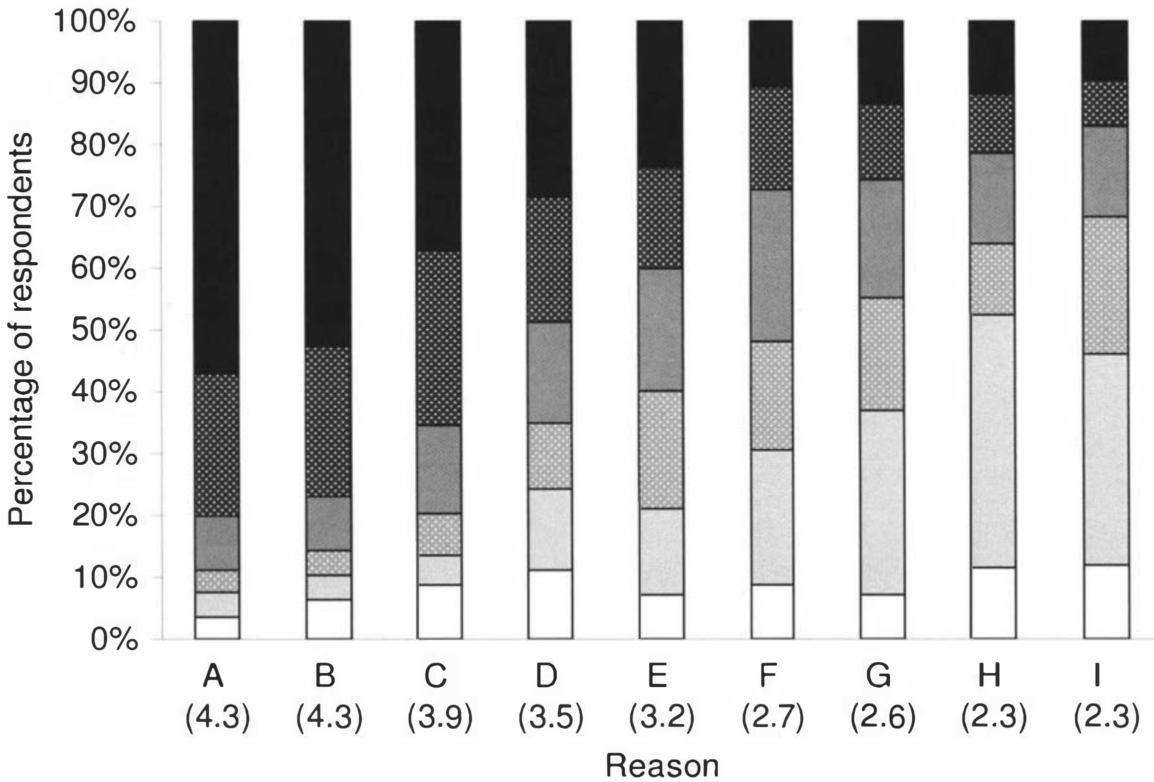
E=Earlier selection of replacements

F=Reduces mature size of heifers so less feed is required for maintenance

G=Eliminates need to keep rising-2-year-old heifers away from bulls

H=Allows you to operate a once-bred-heifer system

I=Fewer mobs over winter



profit" as a very important reason for breeding heifers at 15 months of age. Respondents that had bull-breeding herds were 2.2 times [1.3–3.8 times] more likely than those that had commercial herds to rate "allows earlier selection of replacements" as a very important reason for breeding heifers at 15 months of age. Similarly, they were 7.0 times [3.7–13 times] more likely than respondents that had commercial herds to rate "increased rate of genetic gain" as very important. Respondents that had mixed herds were 2.4 times [1.1–5.0 times] more likely than respondents that had bull-breeding herds to rate "reduces mature size of heifers so less feed required for maintenance" as a very important reason for breeding heifers at 15 months of age.

Reasons against breeding heifers at 15 months of age

Among respondents who had only three-year-old primiparous heifers, the most important reasons for not joining their heifers with a bull at 15 months of age were "concerned about rebreeding performance of two-year-old heifers" and "stunting of heifer's growth and mature size if mated at 15 months" (Figure 3.2). Respondents with bull-breeding herds were 7.4 times [1.7–33.3 times] and 9.4 times [1.5–62.5 times] more likely to rate "don't want a separate line of calves" as a reason not to breed heifers at 15 months of age compared with respondents with commercial or mixed herds, respectively. There were no other differences among the herd types.

Sixty-one percent [50–72%] of respondents who had only three-year-old primiparous heifers in 2006 had bred heifers at 15 months of age in the past. Respondents who had not done so were 3.0 times [1.1–8.2 times] more likely than respondents who had to rate "want a higher pregnancy rate than can be achieved at 15 months" as a reason for not breeding heifers at 15 months of age. Twenty percent [12–31%] of respondents who currently breed heifers for the first time at 27 months of age would change to breeding heifers at 15 months of age if dystocia could be eliminated.

Assistance of primiparous heifers

Rate of assistance was greater ($P<0.05$) for two-year-old compared with three-year-old primiparous heifers (Table 3.2). Range for percentage of heifers assisted was 0–100% (n=0–50) for two-year-old and 0–67% (n=0–5) for three-year-old primiparous heifers. The percentage of three-year-old primiparous heifers assisted at calving was greatest in bull-breeding herds and least in commercial herds ($P<0.05$), but there were no differences among herd types for rate of assistance of two-year-old primiparous heifers.

Figure 3.2. Ratings of reasons for not breeding heifers at 15 months of age. Scale: 1=not important ◻, 2 ▒, 3 ▒, 4 ▩, 5=very important ■; NR=no response ☐. Bars represent the percentage of respondents to a survey of beef breeding cattle farmers in New Zealand that had only three-year-old primiparous heifers in 2006 that selected each rating, or did not respond. The mean rating for each reason is in brackets ('NR' responses were excluded from the mean). Possible reasons presented were:

A=Concerned about rebreeding performance of two-year-old heifers

B=Stunting of heifers' growth and mature size if bred at 15 months of age

C=Need mob (rising-2-year-old heifers) that can be fed less when required

D=High incidence of calving difficulty in two-year-old heifers,

E=Requires different management skills

F=Want a higher pregnancy rate than can be achieved at 15 months

G=Returns do not justify the extra work and costs

H=Unable to grow heifers to suitable live weight for breeding at 15 months

I=Do not want a separate line of calves,

J=2-year-old heifers are poor mothers

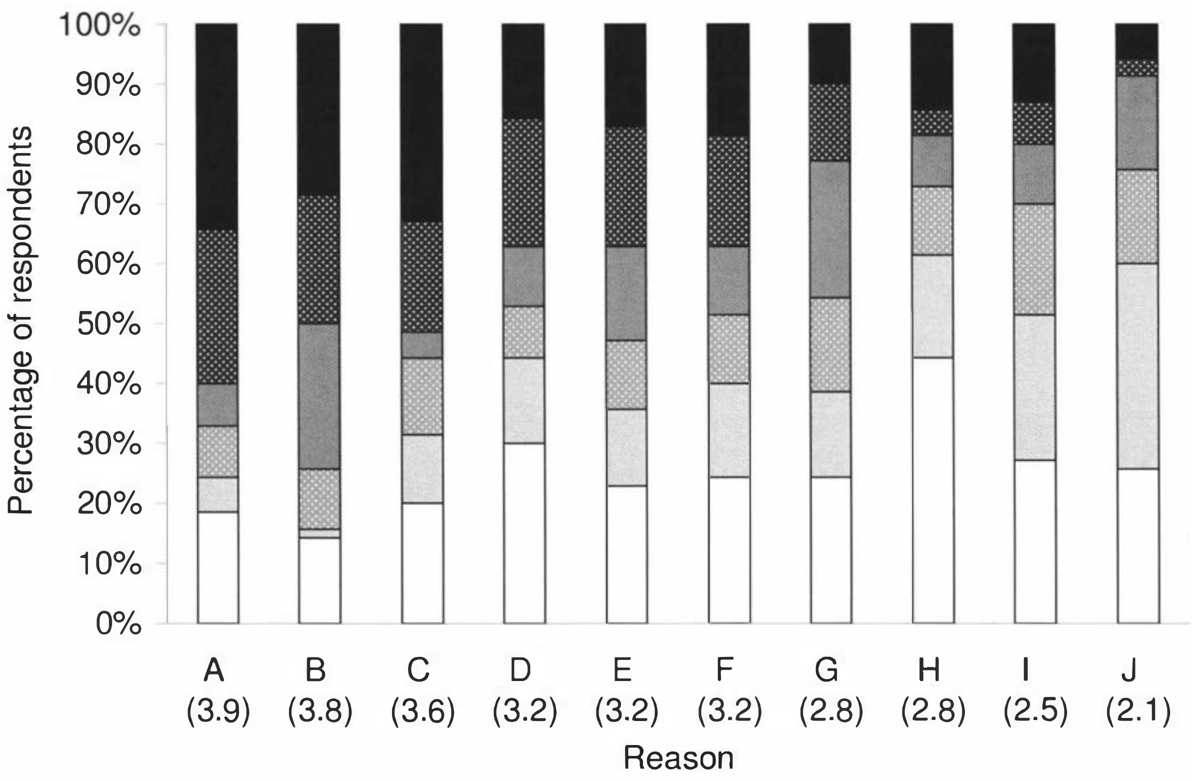


Table 3.2. The LSM percentage (95% CI) of two- and three-year-old primiparous heifers assisted at parturition in all respondents' herds, and in commercial, bull-breeding and mixed commercial and bull-breeding herds in a survey of beef breeding cattle farmers in New Zealand.

	Age of primiparous heifers	
	2 Years	3 Years
All herds	7.0^{a} (6.4–7.5)	1.7^{b} (1.3–2.2)
Within herd types		
Commercial herds	6.3^{cd} (5.8–6.9)	0.7^{f} (0.5–1.0)
Mixed herds	7.3^{c} (6.4–8.5)	1.4^{e} (0.8–2.4)
Bull-breeding herds	7.2^{c} (6.1–8.6)	4.7^{d} (3.2–6.9)

[a, b] Values within rows with different superscripts differ at the P<0.05 level
[c, d, e, f] Values with different superscripts differ at the P<0.05 level

Two-year-old heifers

The most common frequency of observation at calving for primiparous two-year-old heifers was twice daily (Figure 3.3), and probability of assistance increased with increasing frequency of supervision (data not shown). Almost half of respondents (41 [33–49%]) viewed dystocia as 'not a problem' (level 1), and a further 33 [26–41%] rated dystocia as a level-2 problem. Mean percentage of heifers assisted increased with increasing rating for the problem of dystocia (Table 3.3). An increase of 1% in the percentage of two-year-old heifers assisted increased the likelihood of rating dystocia as "a major problem" (score 4 or 5) by 1.08 times [1.04–1.13 times]. At the same rate of assistance, respondents that had commercial herds were 4.4 times [2.3–8.5 times], and respondents that had mixed herds were 2.4 times [1.0–5.4 times], more likely to view dystocia as a major problem compared with respondents that had bull-breeding herds.

The most common strategy for selecting heifers to be bred at 15 months of age was to only join heifers that had reached a suitable minimum live weight (56% of respondents who bred heifers at 15 months; [49–63%]), followed by "put all heifers to the bull" (35% [29–43%]). Among respondents who selected heifers to be joined with a bull at 15 months of age based on a minimum live weight requirement, the mean suitable minimum live weight specified was 305 kg [298–313 kg] for respondents who had only two-year-old primiparous heifers (n=107) and 321 kg [305–338 kg] for respondents that had both two- and three-year-old primiparous heifers (n=22). There was little difference among breeds, although respondents who only calved two-year-old heifers required a

Figure 3.3. Percentage and 95% CI of commercial (□), mixed bull-breeding and commercial (▩), or bull-breeding (■) farmers in a survey of beef breeding cattle farmers in New Zealand that checked their two-year-old primiparous heifers less than once daily, once daily, twice daily or more than twice daily at calving in 2006.

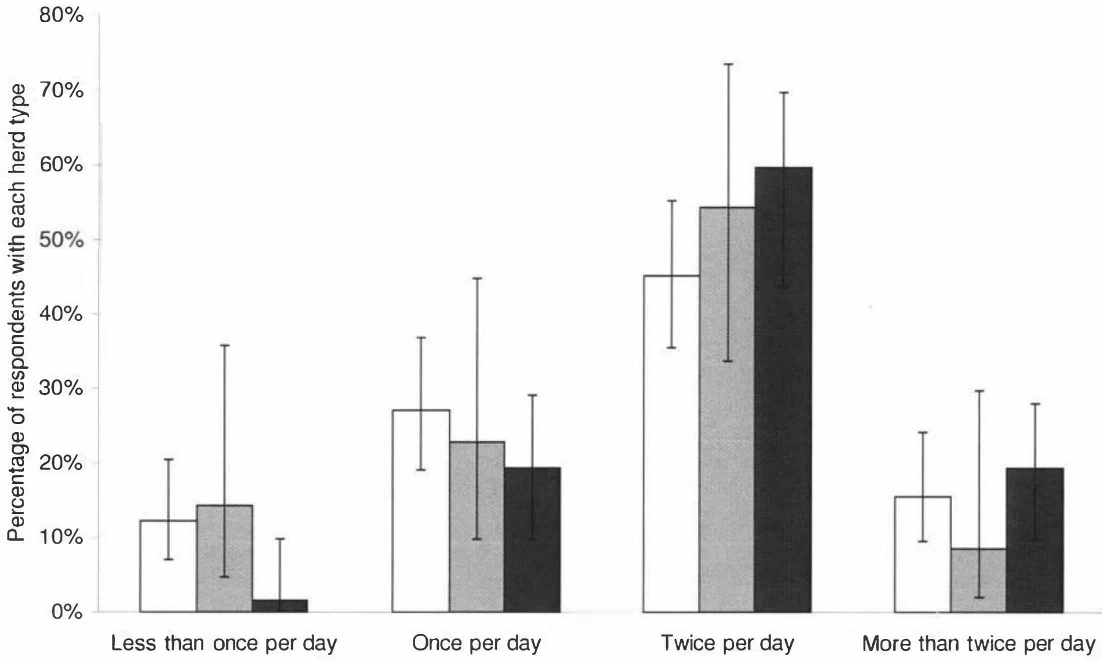


Table 3.3. The LSM, 95% CI, and range in percentage of two-year-old primiparous heifers assisted by respondents who rated dystocia as problem on a scale of 1–5 (1 = not a problem, 5 = a major problem) in a survey of beef breeding cattle farmers in New Zealand. Few respondents in Category 5 meant responses 4 and 5 were merged to preserve anonymity.

Rating	n	Mean (%)	95% CI (%)	Range (%)
1	97	2.3^{d}	1.9–2.8	0–33
2	81	7.3^{c}	6.6–8.1	0–50
3	47	9.7^{b}	8.6–11.0	0–33
4 or 5	17	18.7^{a}	16.0–21.7	0–100

$^{a, b, c, d}$ Values within columns with different superscripts differ at the P<0.05 level greater minimum live weight at mating (P<0.05) for continental breeds of heifers compared with dairy-beef crossbred or Hereford heifers (336 ± 16 kg compared with 301 ± 7 kg and 292 ± 11 kg, respectively).

Selection of bulls to breed with maiden heifers

The factor considered most frequently when selecting bulls to breed with maiden heifers was the EBV for birth weight (Table 3.4). Other important factors were age of bull and body shape of bull. Respondents that had bull-breeding herds were 2.0 [1.0–3.9] and 6.2 [3.0–12.8] times more likely to consider EBV for direct calving ease and gestation length, respectively, and 5.2 times [1.6–16.4 times] more likely to consider breed-specific selection indexes, than respondents that had commercial herds. Most respondents that used age as a criterion for selecting a bull preferred to use a bull that was the same age as the heifers to be bred (Table 3.5). Within respondents selecting bulls based on EBVs, respondents that had commercial herds were 3.9 times [1.9–7.6 times] more likely than respondents that had bull-breeding herds to prefer low EBV for birth weight.

Table 3.4: The probability and 95% CI of respondents considering various factors when selecting a bull to join with 15- (n=252) or 27-month-old (n=107) maiden heifers in a survey of beef breeding cattle farmers in New Zealand.

	15-month-old heifers		27-month-old heifers	
Factor	Prob.	95% CI	Prob.	95% CI
Birth weight EBV	0.80	0.75–0.85	0.73	0.64–0.81
Direct calving ease EBV	0.47	0.41–0.53	0.43	0.33–0.53
200-, 400- or 600-day weight EBV	0.37[b]	0.31–0.42	0.53[a]	0.44–0.63
Gestation length EBV	0.30	0.24–0.35	0.24	0.16–0.33
Selection index	0.08	0.05–0.12	0.05	0.01–0.09
Shape of bull	0.66	0.60–0.72	0.61	0.51–0.70
Age of bull	0.64	0.58–0.70	0.64	0.54–0.73
Live weight at mating	0.16	0.12–0.21	0.16	0.09–0.23
Cost of bull	0.12	0.08–0.16	0.16	0.09–0.23
Bull previously proven over heifers	0.18	0.13–0.23	n.a.	
Same bull as for mixed-aged cows	n.a.		0.47	0.37–0.56

[a, b] Values within rows with different superscripts differ at the P<0.05 level
n.a.=not applicable

Table 3.5. Preferred characteristics of bulls selected for breeding with 15- or 27-month-old maiden heifers in a survey of beef breeding cattle farmers in New Zealand. Values are LSM percentage (95% CI) of respondents who indicated that they selected bulls based on the trait.

Trait	15-month-old heifers			27-month-old heifers		
	High	**Moderate**	**Low**	**High**	**Moderate**	**Low**
Birth weight EBV	2 (1–10)	32[b] (22–43)	66[a] (55–75)	2 (0–13)	58[a] (44–70)	40[b] (27–53)
200-, 400-, or 600-day weight EBV	82 (68–90)	n.a.	18 (10–32)	94 (82–98)	n.a.	6 (2–18)
Direct calving ease EBV	76 (64–85)	n.a.	24 (15–36)	58 (43–72)	n.a.	42 (28–57)
Gestation length EBV	7 (2–19)	n.a.	93 (81–98)	4 (1–24)	n.a.	96 (76–99)
	Maternal	**Terminal**		**Maternal**	**Terminal**	
Selection index	100 (0–100)	0 (0–100)		67 (27–92)	33 (8–73)	
	Shoulders	**Rump**	**Body length**	**Shoulders**	**Rump**	**Body length**
Shape of bull	82 (73–88)	6 (3–13)	12[b] (7–21)	68 (55–78)	6 (2–16)	26[a] (17–39)
	15 months	**27 months**	**Mixed -aged**	**15 months**	**27 months**	**Mixed -aged**
Age of bull	62[a] (50–72)	36[b] (27–48)	2[b] (0–9)	8[b] (3–19)	65[a] (52–77)	27[a] (17–40)

[a,b] Values within preferences within traits with different superscripts differ between heifer age groups at the $P<0.05$ level

n.a.=not applicable because "moderate" was not a possible selection for this EBV

Strategies for managing dystocia in primiparous heifers

Selecting an appropriate bull was the most popular method of managing dystocia in two-year-old heifers in 2006, whereas wintering on hill paddocks was the most popular strategy for managing dystocia in three-year-old primiparous heifers (Table 3.6). The most common strategy listed under "other methods for managing dystocia in two-year-old primiparous heifers" was to break-feed heifers at calving (n=16). Respondents who chose "selected an appropriate bull" as a method of managing dystocia in two-year-old primiparous heifers were 2.8 times [1.3–5.9 times] more likely to select bulls based on EBV for birth weight than respondents who had not chosen "selected an appropriate bull". Respondents who chose "selected an appropriate bull" as a method of managing dystocia in three-year-old primiparous heifers were no more or less likely to have used EBV for birth weight as a criterion, but were 4.1 times [1.7–9.4 times] more likely to have used shape of bull as a criterion when selecting bulls than respondents who had not

Table 3.6. Probability and 95% CI of respondents with two- (n=241) or three-year-old (n=107) primiparous heifers indicating that they used various strategies to manage dystocia in their heifers in 2006 in a survey of beef breeding cattle farmers in New Zealand.

Strategy	2-year-old heifers		3-year-old heifers	
	Prob.	95% CI	Prob.	95% CI
No particular strategies	0.04[b]	0.02–0.07	0.16[a]	0.09–0.23
Selected an appropriate bull	0.81[a]	0.76–0.86	0.49[b]	0.39–0.58
Low feeding in late pregnancy	0.42	0.36–0.48	0.29	0.20–0.38
Low feeding during early pregnancy and/or joining	0.13	0.09–0.17	0.09	0.04–0.15
Wintered on hill paddocks	0.54	0.48–0.60	0.60	0.50–0.69
Only breed from heifers above a minimum weight	0.49[a]	0.43–0.56	0.16[b]	0.09–0.23
Grow heifers well until calving	0.41	0.35–0.47	0.47	0.37–0.56
Generate heifer dams from a sire with a high EBV for daughters' calving ease	0.11	0.07–0.15	0.16	0.09–0.23
Feed hay/other supplements at night to minimise the number of heifers calving during the night	0.04	0.02–0.07	0.07	0.02–0.11

[a,b] Values within rows with different superscripts differ at the P<0.05 level

chosen "selected an appropriate bull". Conversely, respondents who had not used "selected an appropriate bull" as a means of managing dystocia in three-year-old primiparous heifers were 4.5 times [2.0–10.4 times] more likely to have chosen "use the same bull as for mixed-age cows" than respondents who had.

Discussion

A potential limitation of the present survey was that farmers with two-year-old primiparous heifers may have been more likely to participate, thus biasing the results in favour of calving heifers at two years of age. Additionally, an over-representation of bull-breeding herds would introduce bias. In spite of these limitations, the findings of the survey provide an indication of factors contributing to farmers' management decisions regarding primiparous heifers.

The proportion of respondents calving heifers at two years of age in this survey was somewhat higher than results reported previously; 61% in Canterbury in 2004-2005 (Thomas *et al.* 2007), 48% in Waitomo County in 1991 (Parminter *et al.* 1993), and 5.8% in Wairoa County in 1970-1974 (Hanly and Mossman 1977). Nevertheless, these regional surveys may indicate a nationwide increase in the proportion of farmers breeding 15-month-old heifers over time. The current survey indicated that both Canterbury and the King Country (Waitomo) regions were representative of the national situation in terms of age of primiparous heifers. There was no influence of herd size on age of primiparous heifers in this survey. Therefore, it would be reasonable to expect that the true proportion of farmers calving heifers at two years of age lies somewhere between the 61% reported by Thomas *et al.* (2007) and the 76% observed in this survey.

The increased efficiency of breeding heifers at 15 compared with 27 months of age was highlighted by the identification of "increased profit" as the most important reason for breeding heifers at 15 months of age. Similarly, the statement that "returns don't justify the extra costs" rated relatively lowly as a reason for not breeding heifers at 15 months of age, perhaps indicating that even respondents who did not breed heifers at 15 months were aware of the potential financial benefits of breeding heifers at 15 months of age. This is in agreement with the finding that respondents that had a higher beef-breeding cow stocking rate were more likely to breed heifers at 15 months of age, as on those farms, the beef-breeding cow herd would contribute a greater proportion of farm revenue.

The most important reason deterring respondents from breeding heifers at 15 months of age was "concern about rebreeding performance of the heifers", an issue that has been highlighted as a concern by multiple authors (Carter and Cox 1973; Hanly and Mossman 1977; Parminter *et al.* 1993). This concern has only limited supporting data; 30-80% of two-year-old primiparous heifers were diagnosed non-pregnant after the following joining period (Hanly and Mossman 1977), but rebreeding performance of three-year-old primiparous heifers was not reported in that study. In addition, rebreeding of primiparous three-year-old heifers has also been highlighted as a problem in the past (Fielden and McFarlane 1959; Young 1965). Furthermore, Thomas *et al.* (2007) reported that there was no difference in the rebreeding performance of maiden heifers: 8.0% of two-year-old and 8.3% of three-year-old primiparous heifers were diagnosed non-pregnant after rebreeding, compared with a non-pregnant rate of 6.9% for mixed-aged cows. Rebreeding performance of primiparous heifers was 5% greater in herds in which maiden heifers were joined with a bull at least seven days prior to the start of the joining period for the mixed-aged cows (Thomas *et al.* 2007).

Similarly, there is little evidence to support the concern of respondents that breeding heifers at 15 months of age reduces their mature size. When modelling the efficiency of breeding heifers at 15 or 27 months of age, McMillan and McCall (1991) suggested that heifers bred first at 27 months old were lighter than those bred at 15 months of age until joining at 27 months of age, after which time there was no difference in live weight. Reduced mature size rated lowly as a reason for breeding heifers at 15 months of age, and some respondents indicated disagreement with the statement while others rated reduced mature size as a favourable effect.

The high rating of the need for a 'buffer mob' as a reason for not breeding heifers at 15 months of age was consistent with the low rating of the profitability of breeding 15-month-old heifers among respondents not breeding any heifers at 15 months of age. Those respondents may have considered their beef-breeding cow herd primarily as a tool to complement their sheep flock and have been less concerned about the profitability of the herd as a single entity. This hypothesis is supported by previous work, in which it was identified that 91% of beef cattle farmers saw the role of their beef-breeding cow herd as "keeping the grass right for sheep" (Thomas *et al.* 2007) and that farmers who considered beef-breeding cows to be an "easy-care enterprise" were less likely to breed heifers at 15 months of age (Parminter *et al.* 1993).

The importance of dystocia as a deterrent for breeding heifers at 15 months of age (Hanly and Mossman 1977; Parminter *et al.* 1993) was reinforced to some extent by this survey; dystocia had a mean importance of 3.2/5, however, 20% of respondents currently not breeding any heifers at 15 months of age indicated that they would change their policy if dystocia could be eliminated. The need for different management skills to successfully breed heifers at 15 months of age was a deterrent in this survey, as was the case in the survey in Waitomo in 1991 (Parminter *et al.* 1993). This contrasted with a similar survey of sheep farmers, in which "lack of experience" rated 1.55/4 as a reason for not lambing hoggets (Kenyon *et al.* 2004). Carter and Cox (1973) reported that primiparous three-year-old heifers had only 4% more calves present at marking than primiparous two-year-old heifers, a finding that supports the low rating in the present survey of "want a higher pregnancy rate than can be achieved at 15 months" as a reason for not breeding heifers at 15 months of age amongst respondents who had tried breeding heifers at that age in the past.

The calving-assistance rates reported in this survey compared favourably with rates of assistance of 16.7% for primiparous heifers in beef herds in the United States of America, 9.9% of heifer calvings attended by a veterinarian (Dargatz *et al.* 2004) and dystocia rates (defined as number of assisted births plus number of unassisted stillborn calves) of 7–12% of all primiparous heifers (two or three years old) reported in a survey of beef herds in Southern Queensland, Australia (Wythes *et al.* 1976). In that latter survey, 11% of primiparous heifers required assistance at parturition and 4% of heifers and 7% of calves died. Thomas *et al.* (2007) reported 1.4% of two-year-old and 0.5% of three-year-old primiparous heifers died as a result of dystocia. The relative increase in deaths between two- and three-year-old primiparous heifers was much greater in that survey than was the increase in assistance rates between two- and three-year-old primiparous heifers in the present survey. This may indicate that the severity of dystocia in beef heifers that were assisted at calving was greater in two-year-old than in three-year-old heifers, as it was more likely to result in death of the heifer; alternatively, the increase (approximately 1.5 times) in deaths of two- compared with three-year-old heifers in the survey in Canterbury (Thomas *et al.* 2007) was similar to the increase in rates of assistance in commercial herds in this survey, so it may be reflective of a lower proportion of bull-breeding herds in the survey population in Canterbury than in the respondent group of the current survey.

In agreement with previous work (Wythes *et al.* 1976), there was a positive relationship between frequency of observation and rate of assistance of two-year-old heifers in the present study. Information was not collected on survival of heifers and calves, but previous work indicated that survival of heifers could be expected to increase in observed compared with non-observed herds (Hodge *et al.* 1982). The greater frequency of observation in bull-breeding herds may be due to the need to identify calves to dams and record birth weight information on the calves, rather than a greater concern about dystocia. Alternatively, the greater potential value of individual calves in bull-breeding herds may increase the viability of frequent observation and assistance in these herds. These considerations probably contributed to the finding that despite observing heifers less frequently, respondents with commercial herds were more likely than respondents with bull-breeding herds to consider dystocia a major problem. At all points of the 1–5 ‘problem’ scale, there were respondents who reported no assistance in their heifers, which means that some respondents assisted no heifers but still considered dystocia to be a major problem. This may indicate that the growth or survival of calves may have been compromised by dystocia in those herds, even if the heifers were not assisted at calving, or perhaps those respondents had experienced high rates of assistance in the past and remained alert to the potential issues dystocia can cause (Wythes *et al.* 1976).

The minimum live weights of heifers suitable to be bred at 15 months of age specified in this survey were much greater than the minimum of 195 kg for Angus heifers suggested previously (Carter and Cox 1973). The ideal weight recommended by those authors was 215–300 kg, however, many respondents obviously felt that this was too light. The difference may be partially explained by an increase in live weight of heifers as a result of 33 years of genetic progress (mean 400-day weight has increased by 43.3 kg for the Angus breed between 1978 and 2006 (Agricultural Business Research Institute 2006)).

Birth weight of the calf is an important factor contributing to dystocia in beef heifers (Meijering 1984; Rice 1994), and this was reflected in the proportion of respondents who considered the EBV for birth weight when selecting a bull to join with their heifers. The preferences within the EBVs for birth weight and gestation length indicated that most respondents had a good understanding of these EBVs, whereas for direct calving ease a large proportion of respondents indicated a preference for bulls whose calves would be born with less ease (more difficulty). The EBV for direct calving ease indicates the expected genetic influence on ease of calving in purebred two-year-old heifers; a greater, more positive EBV for direct calving ease indicates a greater proportion of non-assisted births (Anonymous 2007). It seems that some respondents were unfamiliar with the interpretation of this EBV, even though they indicated that they considered it when selecting a bull. Some of those respondents would have been mistaken only at the time of completing the questionnaire, but it is also likely that some of the respondents had incorrectly interpreted the EBV for direct calving ease and inadvertently selected for increased dystocia.

Emphasis on shape of bull was consistent with the findings from the survey conducted in Canterbury, in which the most important criterion for selection of breeding bulls was conformation (Thomas *et al.* 2007). Age of bull was also frequently indicated as an important characteristic of the bull, and most respondents preferred a bull the same age as the heifers to be bred. The most obvious explanation for this would be to minimise the risk of damage to the animals from joining with a much larger mate; however, live weight of the bull was one of the least important factors, although it may be that respondents considered they had already accounted for live weight by selecting on age. Carter and Cox (1973) reported that 15-month-old bulls performed as well as two-year-old bulls in a single-sire mating situation, and that no injuries to heifers were observed in more than 9700 matings.

The lesser incidence of assistance at calving in three-year-old compared with two-year-old primiparous heifers was reflected in the greater willingness of respondents to use "no particular strategies" to manage dystocia in those heifers. Selection of an appropriate bull was the most popular strategy for managing dystocia in two-year-old heifers, and it seemed most respondents that used this technique recognised that lesser birth weight was a desirable characteristic of an appropriate bull. Wintering heifers on hill paddocks was as popular as selecting an appropriate bull for respondents calving three-year-old heifers, and may reflect a greater risk of overfatness in those heifers. Respondents who used selection of bulls as a tool for managing dystocia in three-year-old heifers were particularly likely to base that selection on the body shape of the bull, despite previous research showing no effect of body dimensions on assistance (Laster 1974; Nugent and Notter 1991; Nugent *et al.* 1991).

Conclusion

This survey may indicate that the majority of beef cattle farmers are now breeding their heifers at 15 months of age. The predominant barriers preventing more respondents from implementing the practice included concern about rebreeding performance, potential for retarding the growth of heifers, and the need for flexibility of management of rising-two-year-old heifers. Further research into the rebreeding performance of primiparous two-year-old heifers is justified. The survey highlighted differences in management strategies and selection of bulls between respondents with two- or three-year-old primiparous heifers. In most herds, dystocia in two-year-old heifers was considered to be not a problem or only a minor problem; however, the incidence of assistance at calving ranged up to 100%, and 20% of respondents currently breeding heifers to calve first at three years of age would change to calving heifers at two years of age if the risk of dystocia was removed. Therefore, research to identify methods of reducing dystocia in primiparous, two-year-old heifers would also be of benefit to the beef industry.

Implications

This survey highlighted two points of interest. The first point was the discrepancy in the assistance rate between commercial and bull breeding herds, which may reflect a real increase in dystocia, or may be an artefact of more conservative guidelines for initiating assistance at parturition in bull breeding compared with commercial herds. The second point was the variation in respondents' rating of dystocia as a problem relative to the assistance rate of their heifers. Investigation of guidelines for initiating assistance at parturition and of the outcome of assisted calving would be useful. Additionally, assistance rates of up to 100% in primiparous, two-year-old heifers indicated that further research into methods of reducing dystocia in these heifers is necessary.

CHAPTER 4

A survey examining outcomes of assisted parturition in two-year-old, beef breeding heifers in industry

Abstract

A previous survey (Chapter 3) identified that many beef breeding heifers were assisted at parturition in 2006. The outcome of assistance at parturition in industry was not examined in that survey. A two-part questionnaire was sent to 204 respondents to the previous survey relating to management of primiparous heifers (Chapter 3) who had indicated a willingness to participate and had bred 15-month-old heifers in 2006. A total of 131 responses were received to Part A and 109 responses were received to Part B. Information was gathered on breeding management, bulls, calves born, calf deaths and assisted calving. The proportion of calves born to primiparous, two-year-old heifers present at marking was 77% [95% CI 76–78%] of heifers joined with a bull. Overall assistance rate was 9.5% [8.7–10.3%], and 30% [25–35%] of calves assisted at birth were stillborn. The predominant cause of assisted calving was feto-maternal disproportion, and 11% [7–16%] of assisted heifers had died by four weeks post-partum. Assistance rate of heifers and proportion of calves detected at pregnancy diagnosis that were present at marking increased ($P<0.05$) when heifers were observed at least twice daily compared with no more than once daily. Only 16% [9–27%] of respondents would not keep the progeny of their primiparous, two-year-old heifers as replacements. The most common time to first graze heifers with the mature cow herd was between first calving and second joining. Eighty-four percent [82–86%] of heifers that calved at two years of age in 2006 calved again in 2007, 5.1% [3.9–6.6%] were culled after being diagnosed non-pregnant and a further 1.9% [1.2–2.7%] were carried over as empty three-year-old heifers. Heifers were achieving acceptable performance as primiparous, two-year-olds; however, in many herds there was scope to increase the retention of heifers as second-calving, three-year-olds by increasing the pregnancy rate of two-year-old heifers and to increase survival of heifers and calves by reducing the need for assistance at parturition.

Introduction

Breeding beef heifers to calve for the first time at two instead of three years of age is recognised to increase the efficiency and productivity of the breeding cow herd on New Zealand beef cattle farms (McMillan and McCall 1991; Chapter 2). In spite of this, 32% of beef cattle farmers elected to calve some or all of their heifers first at three years of age in 2006 (Chapter 3), and concern about dystocia and rebreeding performance have been highlighted as potential deterrents (Carter and Cox 1973; Hanly and Mossman 1977; Chapter 3).

Breeding of 15-month-old heifers is no longer a new technique and many farmers have been calving heifers at two years of age for many years, with varying degrees of success. Yet, there is little information available that details the performance of these herds, or the strategies employed by the farmers to manage the breeding, calving and rebreeding of primiparous, two-year-old heifers. A recent survey of beef cattle farmers (Chapter 3) identified that 7% of two-year-old compared with 1.7% of three-year-old, primiparous beef heifers were assisted in 2006. In addition, 59% of respondents with two-year-old, primiparous heifers considered dystocia to be a problem to some extent in that survey. Commercial farmers were more likely than bull breeders to consider dystocia to be a problem at the same assistance rate. Reasons for this difference were not apparent from that survey. Furthermore, whilst assistance rate was reported for that survey, the reason for the assistance and fate of the affected animals was not explored.

The aims of this research were to examine via a survey the procedures used by the respondents to the survey in Chapter 3 for managing the breeding and first calving of two-year-old heifers, to quantify the performance of their two-year-old, primiparous heifers, and to investigate the causes and outcomes of assisted parturition of primiparous, two-year-old heifers in these beef breeding cow herds.

Materials and methods

Survey

Participants

Respondents to a previous questionnaire (Chapter 3) were invited to participate in a subsequent survey examining the performance of two-year-old, primiparous heifers. Respondents to the first survey who had indicated that they were willing to take part in a second survey and had bred 15-month-old heifers in 2006 were selected for a direct mail out of questionnaires. A total of 204 questionnaires were distributed in two parts. Part A was sent in August 2007, and Part B was sent in December 2007. Participants who had not yet responded to Part A were sent a second copy of Part A alongside Part B in December. A due date of 31st January 2008 was specified, but responses were accepted until 30th April 2008.

Questionnaire

Part A consisted of 18 questions, and Part B of 23 questions. Both parts had been tested in a pilot survey of 20 farmers and/or students at Massey University. Questionnaires had a unique identification number enabling linking of the two parts with each other and with the original questionnaire. A two-part approach was used to allow collection of data over a prolonged period whilst minimising the risk that respondents may misplace the questionnaire, such as may occur if they were required to keep it for several months.

Part A related to breeding and calving of the heifers. Respondents were asked how many 15-month-old heifers were joined with a bull in 2006, and how many bulls were used. The breed and age of bull was also specified. To avoid potential inaccuracy in calculating the ratio of males:females, respondents were also asked to detail any artificial breeding carried out. The number of heifers that were diagnosed pregnant was requested for herds in which pregnancy diagnosis was carried out. Respondents were also asked to detail how many two-year-old heifers calved in 2007, the date the first and last heifers calved, and the number of primiparous, two-year-old heifers that were assisted at parturition in 2007. Respondents specified the breed of heifer and the number of mature cows (rising-three-year-old and older) carried through the winter in 2007.

Questions regarding the frequency of routine observation of heifers at calving, criteria for deciding to assist a heifer, and the culling policy for assisted heifers, offered a range of potential responses from which respondents could select either one or multiple options. The final question asked respondents to detail for each heifer that they assisted: the apparent cause of the problem, the method of assistance, whether a veterinarian attended, whether the calf was alive at birth and at four weeks of age and the health of the heifer immediately after calving and at four weeks post-partum. Two examples were presented for this question to clarify what was requested. Space was provided for up to 30 assisted heifers.

Part B of the questionnaire asked for the mean birth weight of calves born to two-year-old heifers and calves born to mature cows from those respondents who weighed calves at birth. The number of primiparous, two-year-old heifers and the number of calves born to two-year-old heifers and to mature cows that were present at calf marking was requested. Calf marking was defined to be the time at which calves were earmarked, castrated, dehorned and/or ear tagged (if they were not tagged at birth). A list of potential causes of calf mortality was presented and respondents specified how many calves were lost as a result of each cause. An option of "other cause" was also presented. Respondents were asked how many primiparous, two-year-old heifers calved in 2006, and how many second-calving, three-year-old heifers calved in 2007. They were also asked how many of these second-calving, three-year-old heifers had been bought in after having their first calf elsewhere.

Questions with a range of options to select from related to: two-year-old heifers that rejected their live calf at birth or had no milk; the terrain on which pregnant rising-two-year-old heifers were wintered and calved; the stage at which primiparous heifers first grazed in the same herd as the mature cows; fate of heifers that calved as two-year-olds in 2006 but not as three-year-olds in 2007; timing of selection decisions; and whether calves born to two-year-old heifers were considered for breeding herd replacements.

Statistical analysis

Data management

Respondents were classified for analysis purposes based on type of herd: those with cattle used only for bull breeding (bull-breeding herds), those with commercial cattle only (commercial herds), and those with some bull-breeding and some commercial cattle (mixed herds). In some cases, respondents had completed a single questionnaire for more than one herd, in which case the responses that varied among herds were deleted from the record and new records were created that contained the differing variables (as in Chapter 3).

For reports of individual heifers assisted at parturition, open questions addressed the following factors: cause of problem, method of assistance, health of heifer immediately after parturition and four weeks post-partum. These were grouped into similar responses to create the categories for analysis. Categories for cause of the problem were feto-maternal disproportion, malpresentation of the fetus, failure to progress within a satisfactory time frame, the heifer going "down", inadequate labour effort by the heifer, twins, a decomposing fetus and heifers that were assisted as a precaution (for example, to eliminate the need for the farmer to return later to check on progress). Methods of assistance were categorised into: delivered the calf using manual traction, delivered the calf with some form of mechanical assistance, delivered the calf (method not specified), the farmer extracted the decomposing calf in pieces, called a veterinarian to deliver the calf, the respondent was a qualified veterinarian, or both heifer and calf were already dead when found or were euthanised. Questions relating to the use of veterinary assistance for heifers included an option for the respondents to identify themselves as qualified veterinarians. These were treated as a separate response because it was not possible to distinguish whether or not veterinary attention would have been requested by a lay person in that scenario.

The state of the heifer at calving was classified into 5 categories, and these were further categorised into the classes: 'OK' (including the categories 'healthy' and 'weak/wobbly/sore') and 'Not OK' (including the categories 'paralysed', 'internal damage' and 'dead') to allow stronger comparisons amongst causes and methods of assistance and frequency of observation.

Some questions were left unanswered by some respondents. Numbers of respondents are detailed for most statistics, including all statistics for which the response rate was less than 90%. Responses were audited to remove values that were biologically infeasible (e.g. pregnancy or survival rates greater than 100%). There were no other obvious outliers for any responses.

Statistical analyses

Statistical analyses were carried out using the Statistical Analysis System (SAS version 9.1, SAS Institute Inc., Cary, NC, USA, 2003).

Descriptive statistics (mean and median, standard deviation, range and quartiles for some variables) were calculated at the herd level for the parameters: pregnancy rate (heifers diagnosed pregnant at pregnancy diagnosis per heifer joined); calving rate (heifers calved per heifer joined); rate of assistance (heifers assisted per heifer calved); marking rate (calves marked per heifer joined); survival rate (calves marked per heifer calved), mating ratio (heifers per bull); duration of the calving period; proportion of heifers that calved at two years of age in 2006 that also calved at three years of age in 2007; herd size for each category for time that heifers were first integrated with the mature cows; and mean birth weight on a herd basis for calves born to two-year-old heifers compared with older dams. Herds in which artificial breeding was carried out were excluded from the analysis of mating ratio, and pregnancy rate as affected by mating ratio. Pearson correlation coefficients were calculated between rate of assistance in 2006 and rate of assistance in 2007 within herd type.

Percentage values, LSM and exact 95% confidence intervals (95% CI) were calculated using a generalised model (GENMOD procedure) with a binomial distribution and a logit transformation for the traits at the heifer or calf level: pregnancy rate; calving rate; rate of assistance; marking rate; survival rate; losses of heifers between two and three years of age; mortality of calves between pregnancy diagnosis and marking; cause of assistance; method of assistance; and outcomes of assistance for the heifer and calf at parturition and at four weeks post-partum. This model was also used for traits at the herd level: selection of replacement heifers; culling of replacement heifers; culling of assisted heifers; stage of integration of heifers into mature cow herd; and the use of a veterinarian to attend an assisted calving (excluding herds managed by qualified veterinarians).

A generalised model with a binomial distribution and a logit transformation was also used for traits with various factors fitted as fixed effects: assistance at parturition at the herd level, with herd type as a fixed effect; rejection of calves at the heifer level, with assistance at parturition as a fixed effect; guidelines for providing assistance at the herd level, with and without herd type as a fixed effect; method of assistance at the heifer level, with cause of assistance as a fixed effect; outcomes of assistance at parturition for the heifer and calf immediately and four weeks post-partum, with cause of assistance, method of assistance and frequency of observation as fixed effects in separate models; and health of the heifer four weeks post-partum, with health of the heifer immediately after parturition as a fixed effect. For all generalised models where multiple comparisons were made, a Bonferroni adjustment was made.

Linear models were used to examine the effect of: terrain during winter and herd type on rate of assistance (herd level); bull age and herd type on mating ratio (herd level); mating ratio on pregnancy rate (herd level); stage of integration of heifers into the mature cow herd on the proportion of heifers that calved at two years of age in 2006 that calved again in 2007; and frequency of observation of heifers at calving on the rate of assistance and the proportion of calves detected at pregnancy diagnosis that were present at marking.

Results

Respondents

Two hundred and four respondents to the survey reported in Chapter 3 both indicated a willingness to participate in this survey and bred heifers at 15 months of age in 2006. Responses to both parts A and B were received from 108 of these participants. A further 23 completed only Part A and 1 respondent completed only Part B. Four participants indicated that they were no longer eligible for the survey. Therefore, the response rate was 131/200 (65.5%) for Part A and 109/200 (54.5%) for Part B.

The respondents were responsible for a total of 5143 primiparous, two-year-old heifers in 2007. The majority (82/131; 63%) of respondents had commercial herds, 24% (31/131) had bull-breeding herds and 14% (18/131) had mixed herds. Calving data were collected for 378 assisted heifers in 92 herds (Part A, question 18).

Reproductive success of heifers

Overall assistance rate was 9.5% (Table 4.1). There were no differences amongst herd types in rate of assistance of primiparous, two-year-old heifers. Rate of assistance in 2007 was moderately correlated with rate of assistance in 2006 within commercial herds ($r=0.48$; $n=77$; $P<0.001$), but there was no correlation within mixed or bull-breeding herds (data not shown). Rate of assistance was not affected by the terrain on which heifers were wintered or calved (data not shown). A greater ($P<0.001$) proportion of assisted than non-assisted heifers rejected their live calf (3.2% [95% CI 1.9–5.4%]) versus 0.5% [0.4–0.8%]).

Mating ratios ranged from 3 to 61 heifers per bull. There was no effect of age of bull on mating ratio. Bull breeding herds had a lesser ($P<0.01$) mating ratio (1:20) than commercial herds (1:29). Mixed herds were intermediate (1:27). Herd pregnancy rate at pregnancy diagnosis was not affected by mating ratio.

Replacement heifers

Seven percent [3–17%] of 111 respondents presenting a valid response did not breed their own replacement heifers. Six percent [2–16%] preferred calves born to two-year-old heifers over calves born to mature cows as replacements, 68% [55–78%] had no preference between calves born to heifers or mature cows as replacements, 3% [1–11%] would keep calves born to two-year-old heifers as replacements only if they could not

Table 4.1. Mating ratio, pregnancy rate, calving rate, assistance rate, duration of the calving period, calf marking rate and survival rate of calves for primiparous two-year-old beef heifers on a heifer- and a herd-basis.

	Heifers			Herds	
	n[1]	Rate	95% CI	n[1]	Mean ± s.d.
Mating ratio[2]	7100			133	25.8 ± 13.1 heifers/bull
Pregnancy rate[3]	6455	84%	83–85	107	86 ± 16%
Calving rate[4]	6642	77%	76–78	127	83 ± 16%
Assistance rate[5]	5143	9.5%	8.7–10.3	128	9.6 ± 11.1%
Mean duration of calving period	4682			118	50 ± 20 days
Marking rate[6]	5654	72%	71–73	107	78 ± 20%
Survival rate[7]	4352	93%	92–94	106	94 ± 22%

[1] n is the number of heifers or herds for which the trait was reported.
[2] n herds is greater than 131 because some respondents used a different mating ratio for their commercial versus bull-breeding heifers.
[3] Pregnancy rate = number of heifers diagnosed pregnant per heifer joined with a bull (calculated only for herds in which pregnancy diagnosis was carried out).
[4] Calving rate = number of heifers that calved per heifer joined with a bull.
[5] Assistance rate = number of heifers assisted at calving per heifer that calved.
[6] Marking rate = number of calves marked per heifer joined with a bull.
[7] Survival rate = number of calves marked per heifer calved.

get enough suitable calves from their mature cows, and 16% [9–27%] would only select replacements from calves born to mature cows. Respondents primarily culled potential replacement heifers at weaning (27% [19–36%] of respondents), pre-mating (63% [54–72%]); at pregnancy diagnosis (49% [40-58%]); soon after calving if their calf died (29% [22–39%]); and after weaning of their first calf (37% [28–46%]).

The mean percentage of primiparous, two-year-old heifers from 2006 that calved again at three years of age in 2007 was 84% on a herd-basis for the 86 herds that had at least one second-calving, three-year-old heifer in 2007 and at least one primiparous, two-year-old heifer in 2006. Failure to conceive at 27 months of age was the predominant reason heifers did not remain in the herd from two to three years of age (Table 4.2).

Nine percent [4–18%] of respondents stipulated that they always culled assisted heifers, and a further 16% [9–27%] usually culled them. Heifers were culled in response to assistance only if they did not rear a calf by 33% [23–45%] of respondents, or for very severe cases/if the veterinarian recommended culling by 22% [13–33%] of respondents.

Assistance was not recorded, and therefore, not considered at culling, by 2% [0–10%] of respondents, and 26% [17–38%] did not cull heifers on the basis of assistance at parturition.

The most common time for first grazing heifers with mature cows was after their first calving but prior to their second mating (29% [19–43%], Figure 4.1). Eight percent [3–19%] of heifers were first grazed with mature cows prior to first joining, and 11% [5–23%] were not grazed with mature cows until after third joining. There was no relationship between the stage heifers were first grazed with mature cows and the percentage of heifers surviving in the herd from first to second calving.

Calf parameters

Assistance at birth or evidence of a difficult birth was implicated in the deaths of 3.4% of calves born to two-year-old heifers (Table 4.3). This represented approximately half of the losses of calves from birth to marking.

Mean birth weight of calves born to two-year-old heifers averaged 88% of the mean birth weight of calves born to mature cows in the 40 herds in which calves were weighed at birth (32.0 kg versus 37.4 kg; Figure 4.2). The majority (37/40; 93%) of birth weights were recorded in bull-breeding or mixed herds.

Table 4.2. Fate of heifers that calved at two years of age in 2006 in 90 herds in which fate of heifers was reported.

	n	% of potential	95% CI
Number that calved at two years of age in 2006	3178		
Culled for failing to conceive at 27 months of age	163	5.1	3.9–6.6
Culled on the basis traits other than production	81	2.5	1.7–3.7
Culled for failing to rear a calf at two years of age	65	2.0	1.3–3.1
Carried over as an empty three year old	60	1.9	1.2–2.7
Culled for rearing a substandard first calf	55	1.7	1.1–2.9
Died	42	1.3	0.8–2.2
Culled as part of a once-bred heifer system	41	1.3	0.8–2.2
Number that calved again in 2007	2671	84.0	81.7–86.1

Figure 4.1. Percentage and 95% CI of herds (n=102) in which heifers were first grazed in the same herd as the mature cows at each stage. Stages were:

A=Prior to first joining

B=After first joining but prior to second winter

C=After second winter but prior to first calving

D=After first calving but prior to second joining

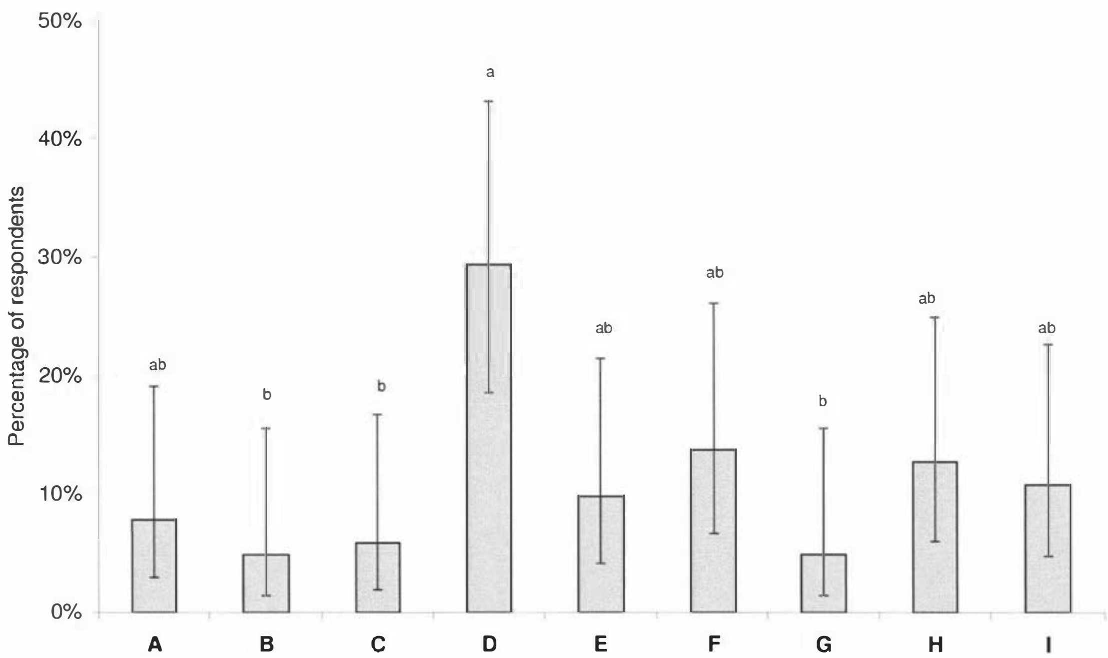
E=After second joining but prior to first weaning

F=At or after first weaning but prior to third winter

G=After third winter but prior to second calving

H=After second calving but prior to third joining

I=After third mating



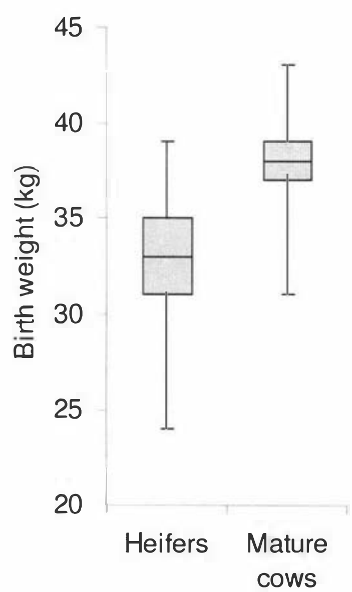
[a, b] Bars without letters in common differ at the P<0.05 level.

Table 4.3. Losses of calves from pregnancy diagnosis or birth to marking in 103 herds in which causes of losses, or no losses, were reported.

	n	% of potential[1]	95% CI
"Potential" calves detected at pregnancy diagnosis	4198		
Losses during gestation[2]	112	2.7	2.2–3.2
Calves born	4224		
Stillborn via an assisted birth	74	1.8	1.2–2.6
Stillborn via a non-assisted birth in which there was no evidence of a difficult birth	53	1.3	0.8–2.0
Stillborn via a non-assisted birth but with evidence of a difficult birth	47	1.1	0.7–1.8
Born alive via an assisted birth but did not survive until marking	23	0.5	0.3–1.1
Died through misadventure	49	1.2	0.7–1.9
Died after being mismothered	14	0.3	0.1–0.8
Died from disease, other or unknown cause	24	0.6	0.3–1.1
Calves present at marking	3938	93.3	91.8–94.5

[1] Potential was number of calves born, except for losses during gestation, which were a percentage of calves detected at pregnancy diagnosis.
[2] Heifer was diagnosed pregnant but not observed to have calved. This was based on 82 herds in which pregnancy diagnosis was carried out.

Figure 4.2. Distribution of mean birth weight within herds for calves born to two-year-old heifers or mature cows.



Management at calving

Assistance rate increased with frequency of observation (Table 4.4) and survival of calves from pregnancy diagnosis until marking was least in heifers checked less than once-daily at calving.

The most common criteria used by respondents as an indicator of the need for assistance of heifers at parturition were: if fetal malpresentation was detected (67% of respondents [58–75%]); if no progress had been made after a certain period of time (59% [50–57%]); or if the heifers had been left unsupervised for some time (e.g. overnight) and the heifer may have already been calving for a long period (57% [49–66%]). Mean time to allow before assisting a heifer was 3.2 hours. A greater percentage of respondents with commercial herds compared with bull-breeding herds assisted heifers if they found them immobile in the paddock (44% [33–55%] versus 23% [11–40%]; $P<0.05$).

Causes and methods of assistance at parturition

Cause of assistance was reported for 347 assisted heifers and could be classified into 8 categories (Table 4.5). The major cause ($P<0.05$) of assisted calving was feto-maternal disproportion, accounting for 50% [43–57%] of assisted calvings, followed by fetal malpresentation, which accounted for a further 27% [21–33%] of assisted calvings.

Method of assistance was detailed for 362 calvings. Eighty-three percent [66–100%] of assisted calvings were resolved by the farmer extracting the calf intact either by hand or with some form of mechanical traction (Table 4.6). Veterinarians were called to assist only 6% [3–10%] of assisted heifers, in 17% [10-26%] of 89 herds managed by non-veterinarian respondents. There were no differences in the method of assistance amongst the causes of the assisted calving (data not shown).

Table 4.4. Assistance rate of heifers, and calves marked as a proportion of the potential calf crop based on pregnancy diagnosis of primiparous, two-year-old heifers observed less than once daily, once daily, twice daily or more than twice daily during the calving period. Values are LSM ± SE.

Frequency of observation	n	Assistance (%)	Calves marked (%)
Less than once daily	6	1.1 ± 1.4^{b}	72 ± 6^{b}
Once daily	23	4.0 ± 2.3^{b}	88 ± 3^{a}
Twice daily	72	10.6 ± 1.4^{a}	84 ± 2^{ab}
More than twice daily	30	12.6 ± 2.0^{a}	87 ± 3^{a}

[a, b] Percentages within columns with different superscripts differ at the $P<0.05$ level.

Table 4.5. Reasons given by farmers for the need for assistance at parturition for 347 primiparous, two-year-old heifers in 2007.

Cause of assistance	LSM (%)	95% CI (%)
Feto-maternal disproportion	50[a]	43–57
Fetal malpresentation	27[b]	21–33
No progress made (reason unclear or not specified)	11[c]	7–16
Heifer assisted as a precaution because farmer is unable or unwilling to return to check progress	6[cd]	3–11
Heifer was 'down' and unable to stand (these heifers were frequently stuck in some form of water hazard)	3[d]	1–6
Inadequate labour effort or vaginal constriction	2[d]	1–5
Heifer attempted to deliver a decomposing fetus	1[d]	0–5
Heifer attempted to deliver twins	1[d]	0–4

[a, b, c, d] Percentages with different superscripts differ at the P<0.05 level.

Table 4.6. Percentage of assisted calvings resolved using various methods in 362 assisted, primiparous, two-year-old heifers in 2007.

Cause of assistance	Mean (%)	95% CI (%)
Calf delivered using hand traction	43[a]	36–50
Calf delivered with mechanical assistance	28[b]	22–35
Calf delivered (method not specified)	11[c]	8–17
Respondent was a qualified veterinarian so calving was attended by veterinarian by default	10[c]	6–15
A veterinarian was called to deliver the calf	6[cd]	3–10
Both heifer and calf were dead when discovered so assistance was no longer needed	2[d]	1–5
Calf extracted in pieces by farmer	1[d]	0–4

[a, b, c, d] Percentages with different superscripts differ at the P<0.05 level.

Outcomes of assisted calving

Of 376 assisted calves for which condition at birth (alive or dead) was recorded, 30% [25–35%] were dead. A further 6% [3–9%] of assisted calves that were born alive had died within four weeks. Calves born to heifers that were assisted as a precaution were more likely ($P<0.05$) to be born alive than calves from all other categories except those assisted after a period in which parturition had not progressed (Table 4.7). Mortality was greater for calves born to assisted heifers in herds observed once daily than in herds observed twice or more than twice daily during calving ($P<0.05$).

Health of the heifer immediately after parturition was reported for 353 heifers (Table 4.8). The majority (76% [70–81%]) of heifers were deemed to be "healthy" after assisted delivery of the calf, whilst a further 8% [5–13%] were classified as "weak/wobbly/sore". Eleven percent [7–16%] of heifers were paralysed, 2% [1–5%] had suffered internal damage and 3% [1–6%] were dead. Dead heifers included those that were dead upon discovery of the problem, and those that were euthanised immediately either because the calf could not be extracted or substantial damage (e.g. uterine prolapse) had occurred during or immediately after parturition. Ninety-four percent [89–97%] of respondents reported that they would attempt to treat a heifer that required treatment to recover from an assisted parturition, and 64% [55–72%] would give treatment that involved a veterinary visit (although half of these would do so only if the veterinarian was already on site).

By four weeks post-partum, most assisted heifers had recovered sufficiently to be classified as 'healthy' (86% [81–90%]) or to have been sold as 'culled' heifers (2% [1–5%]). Eleven percent [7–16%] of assisted heifers were dead, and 1% [0–4%] of assisted heifers appeared to be suffering long-term negative health effects from an assisted parturition.

Table 4.7. Proportion of assisted calves that were alive at birth and at four weeks after birth for calves born to primiparous, two-year-old heifers assisted for various reasons, using various methods and having been observed with different frequencies during calving. Values are back-transformed LSM and 95% CI.

	Birth			Four weeks[1]		
	n	% Alive	95% CI	n	% Alive	95% CI
Cause of assistance						
Feto-maternal disproportion	172	73[bc]	66–79	162	68[c]	60–75
Fetal malpresentation	92	61[cd]	51–70	88	60[cd]	50–70
No progress	38	84[ab]	69–93	37	73[bc]	57–85
Precaution	21	100[a]	74–99	18	94[b]	69–99
Other cause	22	36[e]	19–58	21	32[e]	16–53
Unspecified cause	31	55[de]	37–71	31	48[de]	32–65
Method of assistance						
Pulled – by hand	154	76	69–82	145	71	63–78
Pulled – mechanical assistance	101	74	65–82	94	67	57–76
Pulled – unspecified	41	66	50–79	40	63	48–77
I am a veterinarian	35	69	52–82	33	61	43–76
Called a veterinarian to deliver calf	21	57	36–76	21	52	32–72
Calf extracted in pieces by farmer[2]	2		0	2	0	
Frequency of observation						
Once daily	33	45[b]	30–62	15	93	65–99
Twice daily	234	70[a]	64–76	153	94	89–97
More than twice daily	103	74[a]	64–81	71	94	86–98
All calves	386	70	65–75	358	64	59–69

[1] Calves listed as dead at birth were also included as dead at four weeks of age.
[2] The category calf extracted in pieces by farmer was excluded from the comparisons because there were no live calves so comparisons could not be made with the small group size. Zero values in other categories were replaced with 1 in the statistical analyses to allow comparisons.
[a, b, c, d, e] Values within columns within 'cause of assistance', 'method of assistance', 'frequency of observation' or 'Status immediately after parturition' with different superscripts differ at the P<0.05 level.

Table 4.8. Condition of assisted heifers (percent 'OK') immediately and four weeks after parturition for primiparous, two-year-old heifers assisted for various reasons, using various methods and having been observed with different frequencies during calving. Values are back-transformed LSM and 95% CI.

	Immediately post-partum			Four weeks[1] post-partum		
	n	% 'OK'	95% CI	n	% 'OK'	95% CI
Cause of assistance						
Feto-maternal disproportion	160	83[ab]	76–88	144	86[ab]	79–91
Fetal malpresentation	89	89[a]	80–94	83	93[a]	85–97
No progress	36	97[a]	83–100	37	100[a]	84–100
Precaution	19	100[ab]	72–100	20	100[ab]	73–100
Other cause	19	58[c]	36–77	17	65[c]	40–83
Unspecified cause	29	72[bc]	54–86	29	76[bc]	57–88
Method of assistance						
Pulled – by hand	138	88[a]	82–93	125	95[a]	90–98
Pulled – mechanical assistance	100	87[ab]	79–92	93	88[ab]	80–93
Pulled – unspecified	37	89[ab]	75–96	37	95[ab]	81–99
I am a veterinarian	34	91[ab]	76–97	35	89[ab]	73–96
Called a veterinarian to deliver calf	21	71[b]	49–87	17	82[ab]	57–94
Calf extracted in pieces by farmer[2]	2	100		2	50[b]	6–94
Frequency of observation						
Once daily	27	63[b]	44–79	26	81	61–92
Twice daily	216	88[a]	83–92	198	91	86–94
More than twice daily	103	82[a]	73–88	100	85	77–91
Health immediately post-partum						
Healthy				242	97[a]	94–99
Weak/wobbly/sore				27	96[a]	78–99
Paralysed				35	54[c]	38–70
Damaged internally				5	40[c]	10–80
All heifers	353	84	80–88	330	88	84–91

[1] Heifers listed as dead at parturition were also included as dead at four weeks of age.
[2] The category calf extracted in pieces by farmer was excluded from the first comparison because there were only 'OK' heifers at birth so comparisons could not be made with the small group size. Zero values in other categories were replaced with 1 in the statistical analyses to allow comparisons.
[a, b, c] Values within columns within 'cause of assistance', 'method of assistance', 'frequency of observation' or 'health immediately after parturition' with different superscripts differ at the P<0.05 level.

Discussion

This survey presented the opportunity to further investigate the management and reproductive performance of primiparous, two-year-old heifers, as well as gain greater insight into the on-farm implications of assisted parturition for herds involved in the survey in Chapter 3. A potential limitation of this survey may be that farmers with a greater interest in dystocia (perhaps resulting from a greater incidence of assistance in their heifers) may have been more likely to complete the questionnaires.

The reproductive performance of heifers in this report was comparable with previous studies: the 86% pregnancy rate was similar to reports of pregnancy rates of 15-month-old beef heifers in New Zealand that ranged from 77–90% (Carter and Cox 1973; Morris *et al.* 1993; McFadden *et al.* 2004; Thomas *et al.* 2007). The 78% marking percentage in this survey was greater than the 58–70% reported for two-year-old heifers by Carter and Cox (1973). Thomas *et al.* (2007) reported a weaning percentage (calves weaned per heifer joined) for primiparous heifers of 75.9%, much in line with the marking percentage reported in this survey. In the 2006 survey (Chapter 3), the option "want a higher pregnancy rate than can be achieved at 15 months of age" was more likely to be rated as an important reason for not breeding heifers at 15 months of age by respondents who had not previously bred heifers at 15 months than by respondents who had previously bred heifers at 15 months, perhaps a reflection of 15-month-old heifers having achieved a satisfactory pregnancy rate for those who had bred heifers at this age before. The mating ratios reported in this study were comparable with the 1:28 bull to 15-month-old heifer ratio reported in a survey of beef cattle farmers in New Zealand by McFadden *et al.* (2004).

The lack of correlation between assistance rate in 2006 and 2007 in mixed and bull-breeding herds, combined with the correlation of only 48% in commercial herds, indicated that substantial variation in dystocia may be caused by year effects, such as variation in climatic conditions (affecting temperature as well as the quantity and quality of pasture available to heifers), or variation in the genetic make-up of heifers or calves through the introduction of different sires or maternal grandsires each year. It seems reasonable to assume that the management strategies used would be similar between years within herds. Estimates of heritability for dystocia ranged from 0.03–0.43 for the calf (Philipsson *et al.* 1979; Meijering 1984; Naazie *et al.* 1991; Bennett and Gregory 2001a; Eriksson *et al.* 2004a) and 0.07–0.47 for the dam (Naazie *et al.*

1991; Bennett and Gregory 2001a; Eriksson *et al.* 2004a), indicating a genetic influence, but also indicating that considerable variation in dystocia (or assistance at parturition or birth) would be expected for animals of similar genetic composition.

Selection of replacement heifers from either heifer dams or mature dams was in agreement with the many respondents who used the same bulls over their heifers as their mature cows, indicating that the sires used for joining with heifers (usually sires with low birthweight EBV; Chapter 3) were generally considered suitable as sires for replacement heifers. Selection of replacements from calves born to two-year-old heifers would allow an increased rate of genetic gain, but these calves may have been smaller at the time of selection as a result of a less favourable maternal environment, as evidenced by the lesser birth weights of these calves and previous studies (Morris *et al.* 1986b; Berger *et al.* 1992).

Respondents culled potential replacement heifers prior to joining and at pregnancy diagnosis, but many respondents also culled heifers after they had delivered their first calf. There was considerable wastage of heifers between calving at two and three years of age, largely due to heifers losing their first calf or failing to conceive during joining with bulls at 27 months of age. There are costs associated with rearing these heifers to two years of age only to cull them, however, it is less costly if such heifers can be identified and culled at two rather than three years of age (Chapter 2). In this survey, half of the mortality of calves between birth and calf marking were calves affected in some way by dystocia. Dystocia was also implicated in the wastage of heifers either directly through death/injury to the heifer or indirectly through culling after the death of the calf from dystocia. A reduction in dystocia, and therefore, assistance at parturition, would go some way towards reducing this wastage of replacement heifers and potentially, allow increased selection pressure on other production traits.

A quarter of respondents usually or always culled heifers that were assisted at parturition. An experiment by Brinks *et al.* (1973) revealed that heifers that experienced dystocia at two years of age weaned 11% fewer calves at three years of age compared to heifers that had a normal calving at two years of age, so there may be some justification for this, however, in that study, heifers assisted at two years of age achieved a weaning percentage of 63% at three years of age, indicating that universal culling of assisted heifers would have resulted in unnecessary culling of productive heifers. Assistance at parturition has been reported to have low repeatability – estimates ranged from 0.12 to

0.26 (Phocas and Laloe 2004). Furthermore, Johnson *et al.* (1986) and Sawyer *et al.* (1991) reported no effect on interval to conception of assisted versus non-assisted heifers, whereas Rutter *et al.* (1983) reported that the consequences of assistance at calving were more severe for more severe dystocia. These reports suggest that universal culling of assisted heifers would result in unnecessary wastage of heifers, and a targeted culling approach, such as that used by respondents who culled assisted heifers only if they did not rear a calf or if they experienced "severe" dystocia may be more appropriate.

In agreement with previous work (Wythes *et al.* 1976; Hodge *et al.* 1982), rate of assistance and survival of heifers was greater in herds in which heifers were observed more frequently at calving. The predominant cause of assistance at calving in two-year-old beef heifers was feto-maternal disproportion, in agreement with previous reports (Rice 1994; Odde 1996). Fetal malpresentation also accounted for a considerable proportion of assisted calving and, as expected, a variety of other factors each contributed to a small proportion of cases (Chapter 1). Six percent of assisted heifers were assisted as a precaution against potential dystocia, and, therefore, reports of the number of heifers that required assistance at parturition may be marginally inflated by the inclusion of these heifers that may or may not have eventually required assistance had they been given more opportunity to complete parturition.

Twenty-seven percent of assisted heifers for which the cause of dystocia was reported were assisted due to fetal malpresentation. If these are presumed to be representative for all assisted heifers in this survey, then 2.6% of all heifers that calved required assistance as a result of fetal malpresentation. This was similar to the 2.3% breech or backwards presentations in primiparous, two-year-old heifers reported by Patterson *et al.* (1987).

Respondents generally attempted to deliver the calf themselves before involving a veterinarian. Veterinarians attended only 6% of assisted calvings, indicating that for every heifer that a veterinarian was called to assist, 17 heifers were assisted by a farmer or a farmer/veterinarian. Many calvings (42%) could be considered minor dystocia, in that they were alleviated using hand traction, but a significant proportion required mechanical traction, possibly indicative of more severe dystocia.

In a study reported by Patterson *et al.* (1987), 87% of calf deaths due to dystocia occurred within 24 hours of birth, in agreement with the finding of this survey, in which 89% of deaths of assisted calves that occurred within the first four weeks of life occurred at birth. Eleven percent of assisted heifers for which health at four weeks post-partum was reported had died. This proportion can be projected across all assisted heifers to indicate that 1% of all heifers that calved died within four weeks post-partum. This was similar to the report of 0.3% to 2.5% by Thomas *et al.* (2007). One particularly costly group of heifers was the 8% of assisted heifers that were alive immediately after parturition but died within four weeks; these heifers would have incurred considerable labour and treatment costs during this time.

Despite the report by Morris *et al.* (2006) that young cows would benefit from grazing separately to mature cows at least through to joining at three years of age, 48% of respondents first grazed their heifers with mature cows prior to joining at two years of age. The predominant reason for heifers that calved at two years of age not calving at three years of age was failure to conceive during joining at 27 months of age, supporting the concerns raised by respondents to the 2006 survey that had three-year-old, primiparous heifers (Chapter 3). Delayed integration of heifers with mature cows may go some way towards alleviating this problem (Morris *et al.* 2006), although there was no effect of stage of integration of heifers on the proportion that calved at three years of age in this survey.

Conclusion

Dystocia was involved in half of the losses of calves between birth and marking. Thirty-six percent of calves and 11% of heifers assisted at birth/parturition had died within four weeks post-partum, indicating that dystocia caused substantial wastage on these farms. Observing primiparous, two-year-old heifers at least twice daily during calving was associated with an increased rate of assistance, but also a greater proportion of assisted calves and heifers that survived an assisted delivery, compared with herds in which heifers were observed no more than once daily. Calf marking percentage was least in herds that were observed less than once daily at calving. The respondents achieved pregnancy rates and calf marking percentages in primiparous heifers that were comparable with previous reports. Failure to conceive a second calf was the primary reason for culling heifers between two and three years of age.

Implications

This survey highlighted substantial losses of heifers and calves resulting from dystocia. Combined with the profitability analysis based on these losses in Chapter 2, this reinforces the potential benefits to industry of a reduction of dystocia in primiparous heifers. Variation between years in incidence of dystocia on farms may indicate a potential role for climatic influences on dystocia, and further consideration of nutritional involvement in dystocia would be useful.

CHAPTER 5

Effects of liveweight gain during pregnancy of 15-month-old Angus heifers on assistance at birth, birth weight, body dimensions, estimated milk intake and weaning weight of the calves

Publications arising from this chapter:

Hickson RE, Kenyon PR, Lopez-Villalobos N, Morris ST.
Effects of liveweight gain during pregnancy of 15-month-old Angus heifers on dystocia and birth weight, body dimensions, estimated milk intake and weaning weight of the calves. *New Zealand Journal of Agricultural Research* 51, 171-80, 2008

Abstract

Primiparous, two-year-old heifers are particularly susceptible to dystocia caused by feto-maternal disproportion, therefore, methods of reducing birth weight of calves born to two-year-old heifers would aid in reducing dystocia. Forty-four 15-month-old Angus heifers were allocated to either a moderate (583 ± 73 g/day) or low (193 ± 71 g/day) liveweight gain treatment for the first trimester (93 days) of pregnancy. Both groups were of similar live weight at parturition. Birth weight of the calves and incidence of assistance at parturition were not different between treatment groups, and were 33.0 ± 0.7 compared with 33.8 ± 0.6 kg and 12% compared with 22% for the moderate and low groups, respectively. Body dimensions, live weight from birth to 205 days of age and estimated milk intake of the calves were generally not affected by treatment. Assisted calves had greater estimated milk intake than non-assisted calves at 37 days of age (5.9 ± 1.0 versus 4.1 ± 0.6 kg/day; $P<0.05$). Live weight of heifers during first lactation and intercalving interval between first and second calving were not affected by treatment. Liveweight gain in the first trimester of pregnancy did not affect birth weight of calves or the incidence of assistance at parturition in two-year-old heifers if total liveweight gain during pregnancy was similar between treatments.

Introduction

Heifers of sufficient live weight to have reached puberty are capable of conceiving at 15 months of age, however, only 71% of beef breeding heifers were reported to have calved at two years of age in 2006 in a survey of beef cattle farmers (Chapter 3). Nicol and Nicoll (1987) reported that total lifetime productivity would increase by 0.7 calves per cow if heifers were bred for the first time at 15 instead of 27 months of age, and a simulation of two calving systems showed calving heifers at two years of age was more profitable than calving heifers for the first time at three years of age (Chapter 2).

A high incidence of dystocia in heifers calving at two years of age was one reason for not breeding beef heifers at 15 months of age (Carter and Cox 1973; Parminter *et al.* 1993; Chapter 3). The most prevalent cause of dystocia in heifers was feto-maternal disproportion, a condition in which the fetus is too large to pass through its dam's pelvis without assistance (Rice 1994). Reducing the birth weight of the calf relative to the live weight of the heifer would reduce the incidence of feto-maternal disproportion and, consequently, could reduce the incidence of dystocia in two-year-old beef breeding heifers. Selection of appropriate sires can address the genetic components of dystocia; however, considerable environmental influences on dystocia also exist (Chapter 1). As a result, environmental methods of reducing birth weight, particularly those that could be applied to effect a reduction in birth weight without impairing future performance of the calf or heifer, are of interest in beef cattle production.

Feeding level, or liveweight change, of the heifer is an environmental factor that can be manipulated under pastoral grazing conditions. Studies manipulating feeding level of heifers in late pregnancy have had variable effects on dystocia (Rice and Wiltbank 1972; Laster 1974; Drennan 1979; Kroker and Cummins 1979; Wiltbank and Remmenga 1982; Pleasants and Barton 1992; Spitzer *et al.* 1995). Morris et al. (2004) reported that a significant negative relationship existed between maternal liveweight gain around one month after conception and subsequent birth weight of calves born to mature cows, therefore, it may be possible to manipulate birth weight of calves born to heifers by altering maternal liveweight gain in early gestation. Permanent reduction of live weight of heifers as a result of restricted liveweight gain in early pregnancy is undesirable, so it is of interest whether restricted liveweight gain during early pregnancy but adequate total liveweight gain over pregnancy could influence birth weight of the calf without impacting on maternal live weight at parturition.

The aim of this study was to investigate the effects of varying liveweight gain of 15-month-old beef breeding heifers in the first trimester of pregnancy, while retaining a similar total liveweight gain during pregnancy, on: incidence and severity of assistance at parturition; birth weight, body dimensions, live weight to 205 days of age, behaviour at birth and estimated milk intake of calves.

Materials and Methods

Experimental design

One hundred 15-month-old Angus heifers were allocated to one of two liveweight gain treatments on the day of artificial insemination, balanced for farm of origin (4 source farms), service sire and live weight. The liveweight gain treatments were "moderate" (target liveweight gain of 500 g/day) and "low" (target liveweight gain of 100 g/day) from day of insemination (D0) until day 93 of pregnancy (D93). Heifers in the low treatment were preferentially fed compared with heifers in the moderate treatment from D93 until D236 so that both groups converged to a similar live weight by parturition.

Synchronisation and breeding

On D-10, heifers were injected intramuscularly with 1 mg of oestradiol benzoate (Cidirol®, Bomac Laboratories Ltd., Auckland, New Zealand) and had an intravaginal progesterone-primed controlled internal drug release (CIDR) device inserted (1.38 g progesterone; CIDR®; Pharmacia Ltd., Auckland, New Zealand). CIDR devices were removed on D-2 and heifers were injected intramuscularly with 0.5 mg of cloprostenol (estroPLAN Flexi, Parnell Laboratories New Zealand Ltd., East Tamaki, New Zealand). On D-1, heifers were injected intramuscularly with 1 mg of oestradiol benzoate. Oestrus detection aids (Estrus Alert®, Western Point Inc., USA) were applied on D-2 and heifers were observed for signs of oestrus on D-1 and D0. On D0, all heifers that had displayed oestrus were inseminated, and on D1, all remaining heifers were inseminated, regardless of whether or not oestrus had been observed. Heifers were injected intramuscularly with 0.5 mg oestradiol benzoate on D13 and D20 and the previously-used CIDR devices were reinserted from D13 until D19 as part of a resynchronisation programme.

Frozen semen from four Angus bulls was used for the inseminations (LIC Ltd., Hamilton, New Zealand). EBV for birth weight ranged from +0.2 to +2.6 kg for these bulls (compared with the breed mean of +3.9 kg for 2002-born calves). Pregnancy diagnosis was carried out on D40 using transrectal ultrasound. Fifty-six heifers (n=33 for moderate treatment, n=23 for low treatment) were diagnosed non-pregnant and were removed from the study.

Management of heifers

Treatment groups were managed in separate herds from D0 until D236, at which time they were merged into one herd until cessation of the experiment on D483. Mean day of parturition (L0) was D278. Bulls were joined with the two-year-old heifers at a male:female ratio of 1:54 from L66 to L95, and 1:27 from L95 to L165, allowing the heifers 99 days (4.71 oestrous cycles) to conceive in the subsequent breeding period. Heifers that failed to rear live calves were not considered in post-partum performance measures.

Animal measurements

Heifers

Live weight of unfasted heifers was recorded on D-29, D-2, D33, D61, D93, D114, D148, D182, D215, D245, and D271. Live weight of unfasted heifers was also recorded within 24 hours of parturition, and on mean L36, L58, L87, L114, L189 and L205. Two heifers (low treatment) that had dystocia scores 3 and 4 were not weighed within 24 hours of parturition. Height at withers (Philipsson 1976c) was recorded within 30 days of parturition.

During the calving period, heifers were strip grazed on a daily break in a flat, 1.8 ha paddock to ensure that the heifers could be observed continuously. Record was made of the time at which parturition activity was first apparent (parturition activity included abdominal contractions, discharge of amniotic fluid from the vulva and/or obvious abdominal discomfort), and of the time of appearance of: the amnion, the head of the fetus (defined as both ears external to the vulva), the hips of the fetus, and the rear hooves of the fetus. A normally presented calf was defined to be born once the rear hooves were external to the dam's vulva. After an non-assisted parturition, record was made of the time at which the heifer stood up and the time at which the heifer began grooming the calf. It was also noted whether or not the heifer showed any aggression toward the calf. Full records of parturition were collected on 15 heifers, with partial observations made on a further 7 heifers. The remaining heifers calved unrecorded or unobserved due a variety of factors.

If no progress in parturition had been made after 4 hours, the heifer was yarded and assistance administered as required. The severity of assistance at parturition was scored on a scale of 1–4: 1 = no assistance, 2 = hand assistance, 3 = mechanical traction required or veterinarian-assisted, and 4 = caesarean section or fetotomy required. In the one case of malpresentation, a score was allocated based on the level of assistance required after fetal presentation had been corrected.

Complete placentae were collected wherever possible, and frozen within 12 hours at -20°C for up to 2 months. Placentae were thawed and cotyledons dissected from the fetal membranes. Weight of fetal membranes, total weight of cotyledons, and number of cotyledons were recorded.

Forty-one heifers delivered calves that survived the neonatal period and 39 heifers reared calves to weaning on L205. These 39 heifers were pregnancy tested using rectal palpation on L206 and date of calving was recorded in the subsequent calving period for 29 of the pregnant heifers (n=12 for moderate group, n=17 for low group). Inter-calving interval was calculated for these heifers as the number of days between calving at two years of age and calving at three years of age. Days to calving was calculated as the number of days from first exposure to the bull after calving as a two-year-old until calving at three years of age.

Calves

Post-birth behavioural observations on non-assisted calves included the time at which the calf first stood successfully (on all four feet for 10 seconds or more), and first nursed from any heifer.

Within 24 hours of birth, sex of calf, birth weight, body length, height at withers, depth of body (from the withers to the breast bone), head circumference, shoulder width, heart girth, hip width, left and right forelimb cannon bone circumference and left and right forelimb cannon bone length were recorded (Nugent *et al.* 1991). Calves were standing upright while these measurements were made. Two calves were stillborn and one died within 12 hours of birth. The only parameters measured on these calves were birth weight, sex, head circumference, and left and right forelimb cannon bone circumference.

Live weight of calves was recorded after the calves had been yarded without feed or water for 16–20 hours on L37, L59 and L88. Unfasted live weight was recorded on L189 and L205. Two calves that survived the neonatal period but were not reared to L205 were excluded from all post-birth parameters. Milk intake was estimated using the weigh-nurse-weigh technique (Barton 1970) on L37, L59 and L88.

Statistical methods

All statistical analyses were carried out using the Statistical Analysis System (SAS version 9.1, SAS Institute Inc., Cary, NC, USA, 2003). Duration of parturition variables, behaviour of heifers and calves, placental parameters, dystocia score, birth weight and body dimensions of calves were analysed using the MIXED procedure with a linear model that included the fixed effects of treatment, sex of calf, and assistance at parturition (assisted or non-assisted) where appropriate. Live weight of the heifer within

24 hours of parturition (maternal live weight) and birth weight of the calf were fitted as covariables where indicated. Live weight of heifers and calves and estimated milk intake of calves were analysed using the MIXED procedure considering repeated measures for each animal; the linear model considered the fixed effect of treatment, day, assistance at parturition, and interactions treatment-by-day and assistance at parturition-by-day and the random effect of animal. Sire of calf and farm of origin of heifer were fitted as random effects for all calf variables except estimated milk intake; farm of origin was fitted as the sole random effect for all traits of the heifers and for estimated milk intake of calves. Incidence of assistance at parturition was analysed as a binomial trait (non-assisted = dystocia score 1 versus assisted = dystocia scores 2, 3 and 4) using the LOGISTIC procedure for logistic regression with treatment and sex of calf fitted as fixed effects. Correlations among live weight and estimated milk intake of calves were calculated using the CORR procedure. Not all animals had records for all parameters, so analyses were conducted on as many records as were available (numbers in each analysis are shown).

Results

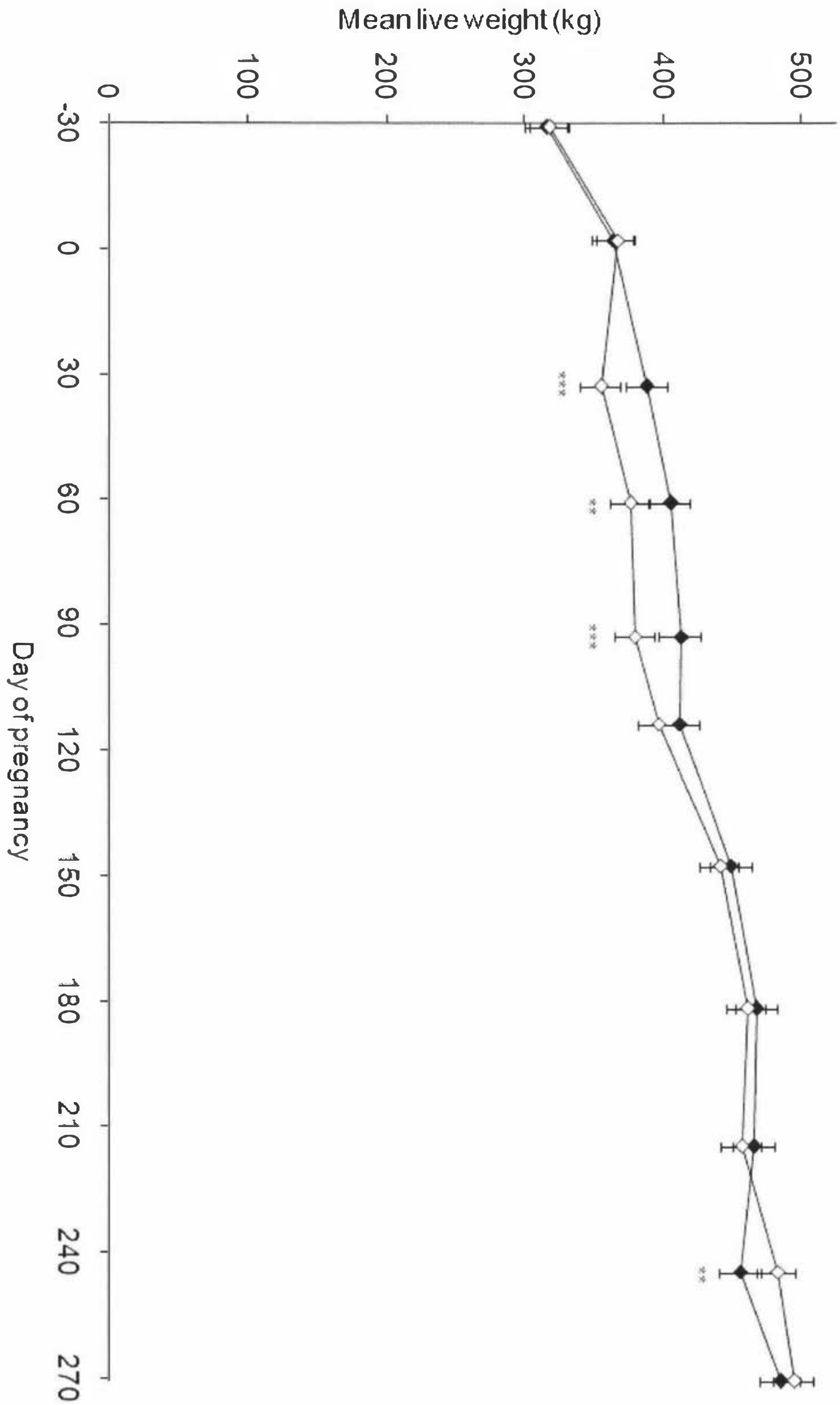
Live weight during pregnancy

The mean live weight on D-2 of the 44 heifers that calved was 364 ± 15 kg for the moderate group and 366 ± 14 kg for the low group (Figure 5.1). From D-2 to D93, the mean liveweight gain of the moderate and low groups was 583 ± 73 g/day and 193 ± 71 g/day, respectively ($P<0.001$). Mean live weight on D93 was 413 ± 15 kg for the moderate heifers compared with 379 ± 14 kg for the low heifers ($P<0.001$). Live weight did not differ between treatments on D-29, D-2, D114, D127, D148, D182, D215, and D271. On D245, the low heifers were heavier ($P<0.01$) than the moderate heifers, but on D271 (first day of calving) live weight was not different between treatments: 484 ± 15 kg and 494 ± 14 kg for the moderate and low groups, respectively.

Parturition parameters

Gestation length did not differ between treatments, sex of calf, or assisted compared with non-assisted heifers: 278.8 ± 1.3 days for the moderate group and 276.9 ± 1.2 days for the low group. Incidence of assistance at parturition was not significantly different between treatments, and 12% (2/17) and 22% (6/27) of heifers were assisted in the

Figure 5.1. Live weight from 29 days prior to insemination until day 271 of pregnancy of heifers that had moderate (◆) or low (◇) liveweight gain for the first 93 days of pregnancy. Values are LSM ± s.e.



* P<0.05, ** P<0.01, *** P<0.001.

moderate and low groups, respectively. Dystocia score was also not affected by treatment, and was 1.4 ± 0.2 in the low group and 1.2 ± 0.2 in the moderate group. Dystocia score was greater (P<0.05) for male than for female calves and tended (P=0.07) to increase with increasing birth weight. Heifers delivering female calves were less likely (P<0.05) to require assistance than heifers delivering male calves (odds ratio 0.070, 95% CI [0.080-0.645]).

Duration of parturition (start of parturition until calf born) and time from appearance of the head until appearance of the hips increased with increasing birth weight, but were not affected by treatment (Table 5.1). Time from appearance of the amnion until delivery of the calf was greater (P<0.05) for the low compared with the moderate treatment. There was no difference between treatments in the time taken for the non-assisted dams to stand after parturition or to begin licking the calf (data not shown).

Table 5.1. Effect on duration of parturition and behaviour of calves born to heifers that calved without assistance and had moderate or low liveweight gain during the first trimester of pregnancy. Values are LSM ± s.e.

	Treatment		Significance			
Time (min.) from	Moderate	Low	Treat-ment	Birth weight	Sex	PPLW[1]
n heifers	8	11				
Head visible till hips delivered[2]	1.6 ± 0.4	1.2 ± 0.4	n.s.	*	n.s.	n.s.
Start of parturition till calf born	145 ± 33	224 ± 29	n.s.	*	n.s.	n.s.
Amnion observed till calf born	14 ± 25[b]	109 ± 22[a]	*	n.s.	n.s.	n.s.
n calves	10	11				
Birth until calf stood	42 ± 12	74 ± 11	0.077	n.s.	*	
Calf stood until calf suckled	18 ± 7[b]	32 ± 7[a]	*	n.s.	n.s.	

[1] Post-partum live weight of heifer, recorded within 24 hours of parturition.
[2] Number of records was 7 for the moderate and 10 for the low treatment.
[a, b] Values within rows with different superscripts differ at the P<0.05 level.
n.s. = not significant, * P<0.05, ** P<0.01, *** P<0.001.

Placental parameters

There were no differences between treatments in the weight of fetal membranes or total weight of cotyledons, but number of cotyledons was greater ($P<0.05$) and mean weight of cotyledons was less ($P<0.05$) in the moderate compared with the low group (Table 5.2). No correlations existed between birth weight and placental parameters, either within or across treatments (data not shown). Total weight of fetal membranes was positively correlated with total weight of cotyledons ($r=0.93$; $P<0.001$) and number of cotyledons ($r=0.75$; $P<0.01$), whilst number of cotyledons was negatively correlated with mean weight of cotyledons ($r=-0.64$; $P<0.05$) across treatments.

Live weight during lactation and rebreeding of heifers

Live weight of the heifers throughout lactation was not affected by treatment. Thirty-eight of the 39 heifers that reared calves to L205 were diagnosed as pregnant on L206. Inter-calving interval and days to calving were not different between treatments: 381 ± 6 and 316 ± 6 days for the moderate group compared with 373 ± 6 and 306 ± 5 days for the low group, respectively.

Calf parameters at birth

Birth weight of calves was not different between treatments (Table 5.3). Calves from heifers in the low treatment had greater ($P<0.05$) head circumference than calves from heifers in the moderate treatment but no other body dimensions were affected by treatment. All body dimensions except body length were proportional to birth weight. Male calves were heavier ($P<0.05$) at birth than female calves and had greater mean forelimb cannon bone circumference ($P<0.001$). Calves that experienced assistance at birth had greater birth weight than calves that were born without assistance (36.0 ± 1.0 kg compared with 32.8 ± 0.5 kg; $P<0.01$).

Calves from the low treatment took longer ($P<0.05$) to suck from a heifer after standing than calves from the moderate treatment (Table 5.1). Time from birth to standing also tended ($P=0.08$) to be longer for calves in the low compared with the moderate treatment. Female calves stood sooner ($P<0.05$) after birth than male calves, but neither birth weight of the calves nor duration of parturition affected the post-birth behaviours considered. The inclusion of maternal aggression toward the calf (binomial trait) in the model for behaviour of calves explained the difference between treatments for both time from birth to standing and time from standing to sucking (data not shown).

Table 5.2. Effect on weight of fetal membranes, total and mean weight of cotyledons and number of cotyledons at term of moderate or low liveweight gain of heifers during the first trimester of pregnancy. Values are LSM ± s.e.

	Treatment		Significance
	Moderate	Low	
n	8	7	
Weight of fetal membranes (g)	2999 ± 300	2837 ± 281	n.s.
Total weight of cotyledons (g)	1503 ± 161	1456 ± 151	n.s.
Mean weight of cotyledons (g)	15.7 ± 1.6[b]	21.1 ± 1.5[a]	*
Number of cotyledons	96 ± 9[a]	71 ± 9[b]	*

[a, b] Values within rows with different superscripts differ at the P<0.05 level.
n.s. = not significant, * P<0.05, ** P<0.01, *** P<0.001.

Table 5.3. Effect on birth weight (kg) and body dimensions (cm) of live calves of moderate or low liveweight gain of heifers during the first trimester of pregnancy. Values are LSM ± s.e.

	Treatment		Significance		
	Moderate	Low	Treat-ment	Birth weight	Sex
n	17	24			
Birth weight[1]	33.0 ± 0.7	33.8 ± 0.6	n.s.		*
Body length	77.8 ± 1.4	78.7 ± 1.3	n.s.	n.s.	n.s.
Girth	73.6 ± 0.5	73.8 ± 0.4	n.s.	***	n.s.
Head circumference[1]	46.1 ± 0.2[b]	47.5 ± 0.2[a]	***	*	n.s.
Mean forelimb cannon bone length[1]	16.6 ± 0.3	16.1 ± 0.2	n.s.	***	n.s.
Mean forelimb cannon bone circumference	11.3 ± 0.1	11.5 ± 0.1	n.s.	**	***
Shoulder width	19.1 ± 0.3	19.1 ± 0.2	n.s.	**	n.s.
Shoulder depth	29.0 ± 0.3	29.3 ± 0.3	n.s.	**	n.s.
Height at shoulder	65.6 ± 0.6	65.5 ± 0.5	n.s.	***	n.s.
Hip width[2]	19.7 ± 0.2	19.6 ± 0.2	n.s.	*	n.s.

[1] Three dead calves were included in these traits so the low group had 27 records.
[2] Number of records in moderate group was 16 for this trait.
[a, b] Values within rows with different superscripts differ at the P<0.05 level.
n.s. = not significant, * P<0.05, ** P<0.01, *** P<0.001.

Table 5.4. Effect on live weight (kg) of calves reared to 205 days of age of moderate or low liveweight gain of heifers during the first trimester of pregnancy. Values are LSM ± s.e.

Age	Treatment			
	n	Moderate	n	Low
Birth[1]	16	33.0 ± 0.7	23	33.6 ± 0.6
37 days	15	65.0 ± 1.4[b]	20	68.7 ± 1.2[a]
59 days	13	84.3 ± 2.0	20	86.6 ± 1.6
88 days	13	116.2 ± 2.7	19	117.2 ± 2.3
189 days	16	214.3 ± 5.2	23	217.0 ± 4.3
205 days	16	235.8 ± 5.4	23	245.6 ± 4.5
Significance		Treatment 0.066		Sex ***
		Treatment x day ***		

[1] These differ from the values in Table 5.3 because these exclude calves not reared to 205 days of age.
[a, b] Values within rows with different superscripts differ at the P<0.05 level.
n.s. = not significant, * P<0.05, ** P<0.01, *** P<0.001.

Table 5.5. Effect on estimated milk intake (kg/day) of calves of moderate or low liveweight gain of heifers during the first trimester of pregnancy, and assistance at birth. Values are LSM ± s.e.

Age	Treatment				Assistance at birth			
	n	Moderate	n	Low	n	Non-assisted	n	Assisted
37 days	15	5.2 ± 0.7[bc]	20	4.7 ± 0.7[c]	30	4.1 ± 0.6[e]	5	5.9 ± 1.0[d]
59 days	13	7.6 ± 0.9[a]	20	5.9 ± 0.9[abc]	29	6.8 ± 0.6[d]	4	6.7 ± 1.3[d]
88 days	13	6.5 ± 0.8[ab]	19	6.0 ± 0.8[abc]	28	6.7 ± 0.6[d]	4	5.7 ± 1.1[de]
Significance		Treatment *				Assistance at birth [n.s.]		
		Treatment x day [n.s.]				Assistance at birth x day [n.s.]		

[a, b, c] Values for treatment groups with different superscripts differ at the P<0.05 level.
[d, e] Values for assistance groups with different superscripts differ at the P<0.05 level.
n.s. = not significant, P>0.1; * P<0.05; ** P<0.01; *** P<0.001.

Table 5.6. Correlations among estimated milk intake (EMI) and live weight of calves at birth and at 37 days of age (L37), L59, L88, L189 and L205.

	Live weight of calf					
	Birth	L37	L59	L88	L189	L205
EMI on L37	0.15 [n.s.]	0.18 [n.s.]	0.17 [n.s.]	0.12 [n.s.]	0.09 [n.s.]	0.05 [n.s.]
EMI on L59	-0.09 [n.s.]	0.00 [n.s.]	0.11 [n.s.]	0.13 [n.s.]	0.08 [n.s.]	0.05 [n.s.]
EMI on L88	-0.12 [n.s.]	-0.04 [n.s.]	0.14 [n.s.]	0.11 [n.s.]	0.15 [n.s.]	0.06 [n.s.]
Birth weight	1.00	0.44 **	0.45 **	0.33 [0.06]	0.43 **	0.40 *

n.s. = not significant, * P<0.05, ** P<0.01, *** P<0.001.

Calf parameters during the rearing period

Live weight of calves from L37 to L205 was not different between assisted and non-assisted calves, and consequently, assistance was dropped from the model. Calves in the low treatment were heavier ($P<0.05$) than calves in the moderate treatment on L37, but there were no other differences in live weight (Table 5.4). Male calves were heavier than female calves throughout the experiment.

Estimated milk intake of calves was not different between treatments on L37, L59 or L88 (Table 5.5). Estimated milk intake of calves in the moderate treatment was greater ($P<0.05$) on L59 than on L37, but there were no differences over time in the low treatment. Estimated milk intake of the assisted calves was greater than the non-assisted calves on L37 but this difference was not maintained later in lactation. Live weight of the calf was positively correlated with birth weight ($P<0.05$) at all ages except L88 (Table 5.6). Live weight of the calf was not correlated with estimated milk intake on any of the days that it was measured.

Discussion

Liveweight gain of the moderate group of heifers was greater than that of the low group during the first trimester of pregnancy, and both groups were the same live weight at parturition. There was a small fluctuation in the live weight of the moderate group in late pregnancy, however, Pleasants and Barton (1987) reported that for the same total liveweight gain, the pattern of liveweight gain in late pregnancy had no effect on birth weight of the calf. The absence of a birthweight difference between treatments in the present study may indicate that provided total liveweight gain is similar, the pattern of liveweight gain over the total duration of pregnancy does not affect birth weight of the calf, at least for the conservative rates of liveweight gain considered here. This result was in contrast to the report that birth weight of the calf was negatively related to liveweight gain of mature cows around one month after conception (Morris *et al.* 2004), although this was retrospective analysis, and liveweight change in later pregnancy was not considered.

The similarity between treatments in weight of fetal membranes and total weight of cotyledons may be indicative of a failure of the treatments to affect placental size. Placentomes can increase in weight at any stage of gestation (Laven and Peters 2001), so compensatory growth of individual placentomes in the low group may have occurred in the second and third trimesters of pregnancy after feeding level and liveweight gain were increased, so that total cotyledon weight at term was similar in both groups. This hypothesis was supported by the lower number but greater mean weight of the cotyledons in the low compared with the moderate treatment, as well as by the negative correlation across treatments of number of cotyledons with mean cotyledon weight.

Neither the incidence of assistance nor the severity of dystocia differed between treatment groups. Far greater numbers of animals per treatment would be required for a 10% difference in incidence of assistance at parturition to be detected, however, similarities between treatments in live weight of the heifers at parturition and birth weight of the calves meant that the incidence of feto-maternal disproportion, the predominant cause of dystocia in beef breeding heifers (Rice 1994), would have been similar between treatments. The incidence of assistance at parturition in this study (12 to 22%) was consistent with other reports of the incidence of assistance at parturition in beef breeding heifers, which ranged from 8.3 to 63.0% (Smith *et al.* 1976; Dufty 1981; Wiltbank and Remmenga 1982; Rutter *et al.* 1983; Bellows *et al.* 1994). The persistent presence of people in or near the paddock may have created a stressful environment, which, along with the conservative guidelines for assistance, could have increased the observed incidence of assistance at parturition (Dufty 1972a), although Doornbos *et al.* (1984) reported that heifers supervised twice daily throughout the calving period quickly became accustomed to the presence of vehicles and people in the paddock.

Body dimensions of calves did not differ between treatments, with the exception of the greater head circumference of calves in the low compared with the moderate group. These similarities were consistent with the absence of a difference in birth weight between the groups, and indicated that skeletal development of the fetus was proportional to fetal weight in both groups. Prior and Laster (1979) reported that fetal weight and crown-rump length at a range of fetal ages were not affected by maternal energy levels.

Kroker and Cummins (1979) reported that heifers on a low feeding level in late pregnancy tended to take longer to calve than heifers on a moderate or high feeding level, despite calves born to heifers on the low feeding treatment having a lesser birth weight than calves from the other two groups. This was consistent with the longer time from appearance of the amnion until delivery of the calf observed in the low group, and in the current study, neither birth weight of the calf nor live weight of the dam affected time from appearance of the amnion until delivery of the calf. Time from start of parturition until delivery of the calf, and from appearance of the head until delivery of the hips increased with increasing birth weight, indicating that mild feto-maternal disproportion may act to increase the duration of parturition in the non-assisted heifers. Differences in duration of parturition may also have been due to variation in the strength of the labour effort (Kroker and Cummins 1979); however, this was not measured in the present study.

The delay in time from standing until the calf suckled in the low compared with the moderate group was also consistent with the observation of Kroker and Cummins (1979), who reported a longer time from birth to suckling in calves born to low-fed heifers. Kroker and Cummins (1979) also reported that calves from the low treatment took longer to stand and this tended (P=0.08) to be the case in the current study. In contrast to the findings of Kroker and Cummins (1979), there were no correlations between duration of birth and post-birth behaviour in the present study. The difference in time to suckle could be fully explained by a greater incidence of maternal aggression towards the calf of the low compared with the moderate heifers in the present study, as fitting the observation of maternal aggression in the model for behaviour of the calf removed the difference between treatments in time from standing to suckling. Similarly, maternal aggression accounted for the tendency toward a treatment effect on time to stand after birth.

More male calves than female calves experienced assistance at birth in this study (7 of 8 assisted calves were male). Male calves have frequently been reported to result in more dystocia cases than female calves (Laster *et al.* 1973; Price and Wiltbank 1978; Lowman 1979; Rutter *et al.* 1983), and this increased incidence of dystocia has been primarily attributed to increased birth weight of male calves (Laster *et al.* 1973; Price and Wiltbank 1978). In the present study, although male calves were heavier than female calves, sex of calf remained a significant contributor to variation in dystocia score after adjustment for birth weight was made, indicating that variation in birth weight was not the sole reason for the effect of sex of calf on dystocia score. Differences between male and female calves in the incidence of assistance at birth after adjustment for birth weight have been reported previously (Lowman 1979; Rutter *et al.* 1983), and differences in the shape of male compared with female calves have been suggested as a contributing factor (Price and Wiltbank 1978). This suggestion did not seem to be supported by the current study, as mean forelimb cannon bone length was the only body dimension that differed between the sexes after correction for birth weight.

Similar estimated milk intake of the calves between treatments was consistent with the similarities between treatments in live weight of the heifers and calves, and was in agreement with the finding of Sejrsen *et al.* (2000). The estimates of milk intake of the calf, and by deduction, milk yield of the heifers in this study were high relative to reports from another study of Angus heifers using the weigh-nurse-weigh technique (Pleasants and Barton 1987), comparable to those reported in a study of mature Angus cows milked using a portable milking machine on days 60 and 89 of lactation (Brown *et al.* 2001), and low relative to experiments using the weigh-nurse-weigh technique in Hereford x Friesian heifers (Burke *et al.* 1998; Peachey and Morris 1998).

Estimated milk intake of the assisted calves was greater than that of non-assisted calves on L37. Greater milk yields in early lactation have been attributed to increased udder development of heifers carrying heavier fetuses compared with heifers carrying light fetuses (Thatcher *et al.* 1980). Birth weight of assisted calves was greater than that of non-assisted calves, however, no correlation existed between estimated milk intake and birth weight in this study. There were no differences in live weight during rearing of the assisted compared with the non-assisted calves, in spite of the increased estimated milk intake of the assisted calves on L37. This may be explained by the report that calves that experienced dystocia had lower growth rates during rearing (Meijering 1984).

The rebreeding performance of the heifers was better than the 64-95% previously reported (Kroker and Cummins 1979; Bellows *et al.* 1982; Spitzer *et al.* 1995; Funston and Deutscher 2004), as 97% of the heifers conceived in the subsequent mating period, however, the mating period was relatively long in the present experiment. Numbers of non-pregnant cows were insufficient to enable statistical analysis, but it appears that the treatments did not affect the rebreeding performance of the heifers. This was supported by the similarities between treatments in days to calving and inter-calving interval.

Conclusion

Low compared with moderate liveweight gain of 15-month-old beef breeding heifers in the first trimester of pregnancy, for the same total liveweight gain during pregnancy, did not affect the birth weight of calves, nor the incidence of assistance at parturition or severity of dystocia. Similarly, liveweight gain treatment generally did not affect body dimensions, live weight during the rearing period or estimated milk intake of the calves.

Implications

This experiment found no effect of maternal liveweight gain in the first trimester of pregnancy on birth weight of the calf; however, the placental differences indicate that there may have been some effect on the conceptus during that time. Further experiments in which heifers were fed for low liveweight gain in the first trimester of pregnancy and to remain lighter throughout the remainder of pregnancy compared with heifers fed for high liveweight gain in early pregnancy would assist in identifying any affects on the conceptus.

CHAPTER 6

The effect of liveweight gain of pregnant 15-month-old Angus heifers on the live weight of their first and second calves and milk intake of their first calves

Publications arising from this chapter:

Hickson RE, Lopez-Villalobos N, Kenyon PR, Morris ST.
The effect of liveweight gain of pregnant 15-month-old Angus heifers on the live weight of their first and second calves and milk intake of their first calves
Animal Production Science 49, 112-120, 2009

Abstract

Nutritional methods of manipulating birth weight of calves would be useful to beef cattle farmers as a tool for managing dystocia, particularly in two-year-old heifers. This experiment examined the impact of liveweight gain during pregnancy on birth weight, live weight to weaning, body dimensions and milk intake of the calves, as well as subsequent live weight and maternal performance of the heifers. Treatments were high (1220 ± 120 g/day; H) or moderate (560 ± 110 g/day; M) liveweight gain for 10 days prior to conception, and moderate liveweight gain (540 ± 300 kg/day; M) or liveweight loss (-110 ± 300 kg/day; L) for the first trimester (93 days) of pregnancy. HL heifers delivered calves that were lighter absolutely and relative to post-partum live weight of the heifers than the HM, MM or ML heifers. The 8–15% reduction in birth weight could have a substantial impact on incidence of dystocia, but mechanisms for the reduction were unclear. Liveweight gain treatments had no effect on body dimensions or milk intake of the calves. MM and HM calves were heavier during the rearing period than ML calves. There was no effect of treatment on days to calving or inter-calving interval between first and second calves. Conception rate at the third joining period was not different among treatments. The liveweight gain treatments applied achieved a reduction in birth weight and generally had only minor effects on the subsequent performance of the heifers.

Introduction

Breeding heifers to calve first at two instead of three years of age offers a method of increasing the productivity and efficiency of the beef breeding cow herd in New Zealand (McMillan and McCall 1991; Chapter 2). In spite of this, some farmers are reluctant to implement the practice due to the perceived risk of dystocia in first-calving two-year-old heifers and the potential impact on the future productivity of the heifer (Carter and Cox 1973; Parminter *et al.* 1993; Chapter 3). The most prevalent cause of dystocia in two-year-old beef heifers is feto-maternal disproportion, a problem that could be alleviated by restricting the birth size of the calf relative to the size of the heifer (Chapter 1).

Birth weight of calves can be regulated by the selection of appropriate (low birth weight) service sires for heifers; however, birth weight is positively, genetically correlated with future live weight of the animal (Koch *et al.* 2004) and calves that are lighter at birth are likely to have lighter carcasses at slaughter. Therefore, environmental methods of reducing birth weight without compromising future performance of the calf or heifer should be investigated.

Restriction of maternal feed intake or liveweight gain in late pregnancy did not consistently reduce dystocia (Rice and Wiltbank 1972; Kroker and Cummins 1979; Pleasants and Barton 1992), and has been associated with an increased post-partum anoestrous interval of the heifers (Bellows *et al.* 1982). The experiment in Chapter 5 showed no difference in birth weight or live weight at 205 days of age of calves born to heifers that had been fed for 'moderate' or 'low' liveweight gain for the first 93 days of pregnancy, but had the same total liveweight gain during pregnancy. Conversely, Morris *et al.* (2004) reported that a negative correlation existed between liveweight gain of mature Angus cows around one month after conception and birth weight of the calf using retrospective analysis. This indicates that maternal liveweight gain in early pregnancy may affect birth weight of the calf if liveweight gain during the remainder of pregnancy was similar among heifers. It is unknown how such treatment would affect the subsequent performance of heifers and their calves. This must also be investigated to ensure that any short-term benefits achieved are not countered by long-term implications for performance.

In addition to investigating the effects of such treatment on the heifers and their calves, consideration must also be given to the underlying mechanisms of any effects. Evidence exists for a stimulatory role of progesterone in elongation of the conceptus (Garrett *et al.* 1988; Carter *et al.* 2008). A high plane of nutrition was accompanied by a reduction in maternal plasma progesterone concentration in early pregnancy in ewes (Cumming *et al.* 1971; Parr 1992), however, the relationship between nutrition and progesterone concentration is less clear in cattle (Robinson *et al.* 2006).

Follicular development in cattle occurs in waves every 8-10 days throughout the oestrus cycle and within each wave a dominant follicle develops and maintains its size for 5-7 days (Lucy *et al.* 2004). Therefore, maternal liveweight change during the 10 days prior to insemination may influence embryonic development in two ways; firstly by impacting directly on the development of the oocyte that was ovulated and fertilised (Murphy *et al.* 1991), and secondly, by determining the metabolic state of the heifer at the time of conception. Such effects could potentially interact with maternal liveweight change in the first trimester of pregnancy to affect the development of the fetus.

Substantial placental development occurs within the first trimester of pregnancy. Number of placentomes was relatively fixed by day 70 of gestation, although placentomes increased in size and weight, and accessory placentation occurred throughout pregnancy (Laven and Peters 2001). Birth weight of the calf was positively correlated with weight of cotyledons and weight of fetal membranes in calves born to Angus-Hereford crossbred heifers (Echternkamp 1993).

The aim of this experiment was to determine whether maternal liveweight gain for the 10 days prior to insemination and for the first 93 days of pregnancy affected maternal plasma progesterone concentration in early pregnancy, weight of fetal membranes, birth weight, live weight up to 208 days of age or milk intake of the calves, or subsequent productivity and live weight of the heifers.

Materials and Methods

Experiment 2.1

Treatments

The experiment considered liveweight gain treatments over two periods. Treatments consisted of high or moderate liveweight gain for the 10 days prior to insemination (Period 1) and moderate or negative liveweight gain for the first 93 days of pregnancy (Period 2), with a crossover between treatments on the day of insemination (D0). The four treatment groups were: HM (high liveweight gain for the 10 days prior to insemination and moderate liveweight gain for the first 93 days of pregnancy); HL (high liveweight gain for 10 days prior to insemination and liveweight loss for the first 93 days of pregnancy); MM (moderate liveweight gain for 10 days prior to insemination and the first 93 days of pregnancy); and ML (moderate liveweight gain for 10 days prior to insemination and liveweight loss for the first 93 days of pregnancy). Heifers were allowed an 11-day adjustment period (D-21 to D-10) to the initial liveweight gain treatment prior to Period 1. During each treatment period, heifers on the same treatment grazed in a single herd. From the end of Period 2, the HM and MM heifers continued to be grazed together, and the HL and ML heifers continued to be grazed together and target liveweight gains were similar for both herds. Actual growth rates achieved were greater for the HM and MM heifers than for the HL and ML heifers (Table 6.1). Liveweight gain was manipulated by altering the pasture allowance of the heifers.

Animals

Two-hundred and twenty-six 15-month-old, Angus heifers of unknown genetic merit were allocated to one of the four treatment groups at the beginning of the adjustment period on D-21. Treatment groups were balanced for initial live weight and farm of origin (6 source farms; heifers had been present at the research unit for a minimum of one month prior to D-21). Oestrus was synchronised in the heifers using the programme detailed in Chapter 5, except that all heifers were inseminated at a fixed-time insemination on D0, 48 to 52 hours post CIDR removal. Heifers were resynchronised to allow those that had not conceived to the first insemination to be used in a separate experiment (Chapters 8 and 10). Heifers were randomly allocated semen from one of five service sires (BeefPac, LIC, Hamilton, New Zealand) after allowing for treatment, farm of origin and initial live weight.

Seventy-seven heifers were diagnosed pregnant to first insemination on D42, of which six heifers were removed from the experiment prior to or at parturition, due to misadventure (n=1), abortion (n=1), fetal abnormality (n=1), twinning (n=1) or misidentification of calves (n=2). Mean day of parturition (L0) for heifers delivering live calves was D280. From day of parturition, heifers with live calves were allocated to either an early- or a late-calving herd (a spread of calving dates resulted from natural variation in gestation length from a single insemination date), balanced for treatments, until L155 when all heifers were grazed in one herd. Heifers were supervised continuously at calving. Two mature Angus bulls were joined with each herd from L112 until L155, allowing the heifers 43 days (approximately two oestrous cycles) to conceive. Male calves were castrated on L38 for the early-calving herd and on L45 for the late-calving herd. All calves were weaned on L208.

Neonatal deaths due to dystocia, misadventure and rotavirus accounted for 5, 1 and 4 calves, respectively, and two heifers and their calves were excluded from the weight recorded on L208 due to injuries sustained by the heifers.

Measurements on heifers

Unfasted live weight was recorded on D-21, D-10, D-2, D19, D42, D73, D93, D121, D161, D196, D226, D243, and D268. An additional unfasted live weight was recorded within 5 days pre-partum, and within 24 hours post-partum for each heifer. Unfasted maternal live weight was also collected on L57 and L86 for the early-calving herd, on L64 and L93 for the late-calving herd, and on L155, L182 and L208 for all heifers that reared calves to L208. Body condition score was assessed using visual assessment on a scale of 1–5 (1 = emaciated, 5 = obese) on D268.

Blood samples (5 ml) were taken using 20 gauge 1 inch needles into 10 ml vacutainers containing sodium heparin (Becton Dickinson, Preanalytical Solutions, Franklin Lakes, USA) by venepuncture of the coccygeal vein on D13 (prior to reinsertion of the progesterone-primed controlled internal drug release device), D42 and D93 from 42 heifers (n=8–14 per treatment). Samples were immediately placed on ice and then centrifuged at 3000 rpm for 15 minutes. Plasma was frozen at -20°C until it was analysed at the Institute of Food Nutrition and Human Health Nutrition Laboratory, Massey University, using a coated-tube radioimmunoassay (Diasorin, Stillwater, Minnesota) to determine progesterone concentration.

Placentae were collected wherever possible (n=5 HM; n=4 HL; n=8 MM, n=14 ML) and refrigerated for up to 7 days before cotyledons were dissected from the fetal membranes. Total weight of membranes, weight of cotyledons and number of cotyledons was recorded. Mean cotyledon weight was calculated as

$$\frac{total\ weight\ of\ cotyledons}{number\ of\ cotyledons}.$$

Pregnancy diagnosis was carried out using rectal palpation on L210 to detect the second pregnancies of the heifers.

Measurements on calves

All calves were weighed within 24 hours of birth, and sex of calf was recorded. Additionally, body length, height at withers, depth of shoulders (from the withers to the breast bone), circumference of head, width of shoulders, thoracic girth, width of hips, and length and girth of left and right forelimb cannon bones were recorded on the live calves (Nugent *et al.* 1991). The distance between the top of the two scapula bones was also recorded, as was the distance between the top of the left scapula and the top of the greater tubercle of the left humerus. Calves were standing upright while these measurements were made.

Milk intake of the calf was estimated at a mean age of 40, 60 and 89 days (L38, L57 and L86 for the early-calving herd and L45, L65 and L94 for the late-calving herd) using the weigh-nurse-weigh technique (Barton 1970). Fasted live weight of calves was also recorded on these days. Unfasted live weight of calves was recorded at 155, 182 and 208 days of age.

The 40 surviving female calves born to the two-year-old heifers were managed under commercial conditions until 16 months of age. Unfasted live weight was recorded on D758 (16 months of age) for these heifers.

Experiment 2.2

Animals

At pregnancy diagnosis to detect second pregnancies (L210), 10 heifers were randomly selected from each treatment from Experiment 2.1 after excluding empty heifers and heifers whose calves weighed less than (arbitrarily) 35% of the heifer's live weight at weaning. Selected heifers were managed commercially in a single herd until weaning of their second calf (D820, 132 days after mean date of second calving). Three of the 40 heifers were excluded from all records in Experiment 2.2 because of twinning (n=2) and prolonged severe ill-thrift (n=1). Oestrus was synchronised to occur 73 days after mean date of second calving using a progesterone and GnRH programme (Laven 2008). Heifers were inseminated using fixed time insemination at this synchronised oestrus. Male second calves were castrated at a mean age of 63 days.

Measurements on heifers

Date of second parturition was recorded and used to calculate inter-calving interval (days between birth of first and second calf) and days to calving (number of days between first exposure to bull after first calving until birth of the second calf). Unfasted live weight was recorded 28 days before and 63 and 132 days after mean date of second parturition. Pregnancy diagnosis to detect the heifers' third pregnancies was carried out using rectal palpation 48 days after insemination to the synchronised oestrus.

Measurements on second calves

Calves were weighed within 24 hours of birth and sex of calf was recorded at this time. Unfasted live weight was recorded at a mean age of 63 and 132 days.

Statistical analyses

Experiment 2.1

Statistical analysis was carried out using the Statistical Analysis System (SAS version 9.1, SAS Institute Inc., Cary, NC, USA, 2003). Live weight from D-10 until D268 was analysed using a linear model in the MIXED procedure with Period 1, Period 2, Period 1 by Period 2 interaction, sex of calf, day of measurement and Period 1 by Period 2 by day of measurement interaction fitted as fixed effects. The random effects of farm of origin, service sire and the random effect of heifer to allow for repeated measures were considered. Similarly, average daily liveweight gains from D-2 to D268 were analysed using linear models in the MIXED procedure with Period 1, Period 2 and Period 1 by Period 2 interaction fitted as fixed effects. Farm of origin and service sire were fitted as random effects. Average daily liveweight gain from D-10 to D-2 excluded the effect of Period 2 from the model, because this parameter was measured before Period 2 had occurred. Pre-calving and post-calving live weight were also analysed using a linear model in the MIXED procedure with Period 1, Period 2 and Period 1 by Period 2 interaction fitted as fixed effects. The number of days pre-calving (1–5) that a heifer was weighed was included as a covariable for pre-calving live weight only. Farm of origin of heifer and service sire were considered as random effects. Live weights from calving to weaning were analysed using a linear model in the MIXED procedure with Period 1, Period 2 and Period 1 by Period 2 interaction, assistance at calving (0 = non-assisted; 1=assisted), day of measurement and the interaction of day of measurement with Period 1 and Period 2 as fixed effects and farm of origin of heifer, service sire, and heifer as random effects to allow for repeated measures. Body condition score pre-calving was analysed using the GENMOD procedure with Period 1, Period 2 and Period 1 by Period 2 interaction as fixed effects.

Plasma progesterone concentration was analysed as a repeated measure with the fixed effects of Period 1, Period 2, Period 1 by Period 2 interaction, day of measurement and day of measurement with Period 1 and Period 2 interactions, and the random effects of farm of origin of the heifer, service sire and heifer to allow for repeated measures.

Placental parameters were analysed using linear models in the MIXED procedure with treatments and treatment interactions considered as fixed effects and farm of origin of heifer and service sire as random effects. Sex of calf was considered as a fixed effect but was not significant so was excluded from the model. Models for placental parameters were run with and without birth weight of the calf as a covariable. Pearson correlation coefficients were calculated using the CORR procedure.

Birth weight of the calf and liveweight loss at parturition were analysed using a linear model in the MIXED procedure, with Period 1, Period 2 and Period 1 by Period 2 interaction and sex of calf as fixed effects and service sire and farm of origin of heifer as random effects. Models were run with and without post-partum live weight of the heifer as a covariable. The model for liveweight loss at parturition also included the number of days pre-calving that pre-calving live weight was recorded as a covariable. Linear models within the MIXED procedure were used for body dimensions, with birth weight of the calf as a covariable and sex of calf, Period 1, Period 2 and Period 1 by Period 2 interaction as fixed effects. Service sire and farm of origin of heifer were fitted as random effects. Few (two) empty heifers at pregnancy diagnosis to detect second pregnancies meant no statistical analysis was carried out on this data.

Milk intake of calves was analysed using a linear model for repeated measures within the MIXED procedure. Fixed effects were sex of calf, Period 1, Period 2, day of measurement, and Period 1 by Period 2 by day of measurement interaction. Date of birth of calf was fitted as a covariable and service sire, farm of origin of heifer, and calf were fitted as random effects. Similarly, live weights of calves from birth to weaning were considered as repeated measures using a similar model as for milk intake, except for the addition of grazing herd (early or late-calving). Grazing herd was considered as a random effect on milk intake but did not contribute to variation in the trait and was excluded from the model. Average daily liveweight gain of calves from birth to weaning was analysed using the same model as birth weight of the calf, however, sex of calf did not contribute to variation in this trait and was consequently excluded from the model.

Experiment 2.2

Live weights of heifers were analysed using a linear model for repeated measures with Period 1, Period 2, day of measurement and interactions as fixed effects and farm of origin of the heifers and heifer as random effects. Live weights of calves were also analysed using repeated measures, with Period 1, Period 2, day of measurement and interactions as fixed effects and calf as a random effect to allow for repeated measures.

Days to calving and inter-calving interval were analysed using a linear model in the MIXED procedure, with Period 1, Period 2 and Period 1 by Period 2 interaction as fixed effects. Pregnancy rate at pregnancy diagnosis to detect third pregnancies was analysed as a binomial trait using a logistic regression model in the GENMOD procedure after logit transformation. Period 1, Period 2 and Period 1 by Period 2 interaction were fitted as fixed effects.

Results

Experiment 2.1

Heifers

There were no differences among treatments in initial live weight (D-21) of the heifers. During the first treatment period, liveweight gain of the heifers was 1220 ± 120 g/day for the high treatment and 560 ± 110 g/day for the moderate treatment (P<0.001). In the second period, heifers in the moderate treatment gained 540 ± 30 g/day, whilst heifers in the liveweight loss treatment lost 110 ± 30 g/day (P<0.001). Mean daily liveweight gain from D93 to D268 was greater (P<0.05) for the HM and MM treatments compared with the HL and ML treatments (Table 6.2). Conversely, from day of parturition until L208, heifers in the HL and ML treatments grew faster than heifers in the HM and MM treatments.

These differences in rate of liveweight gain contributed to differences in live weights. At the end of the second treatment period (D93), the HM and MM groups were similar to each other, and were heavier than the HL and ML groups (P<0.05). Pre- and post-partum live weight was greater for the HM and MM groups than for the HL and ML groups (P<0.05), but body condition score on D268 was greater for the HM and MM groups only compared with the ML group (P<0.05). On L208, the HM and HL groups no longer differed in live weight. Assisted heifers were lighter (P<0.05) than non-assisted heifers throughout lactation.

Table 6.1. LSM ± s.e. for liveweight gain (g/day) of heifers fed for high (H) or moderate (M) liveweight gain for 10 days prior to insemination (P1; first letter), and for moderate (M) liveweight gain or for liveweight loss (L) for the first 93 days of pregnancy (P2; second letter) during Experiment 2.1.

	Treatment group				Significance		
	HM	HL	MM	ML	P1	P2	P1 x P2
D-2 to D93[1]	540 ± 40[a]	-90 ± 40[b]	550 ± 40[a]	-130 ± 40[b]	n.s.	***	n.s.
D93 to D268	550 ± 30[a]	310 ± 30[b]	530 ± 30[a]	380 ± 30[b]	n.s.	***	0.075
Parturition to L208	280 ± 30[b]	440 ± 40[a]	300 ± 30[b]	450 ± 40[a]	n.s.	***	n.s.

[1] Treatments began on D0, but live weight was recorded on D-2 to avoid weighing heifers in oestrus.
[a, b, c] Values within rows with different superscripts differ at the P<0.05 level.
n.s. = not significant, P>0.1; * P<0.05; ** P<0.01; *** P<0.001

Table 6.2. LSM ± s.e. for live weight (kg) and body condition score (1–5 scale) of heifers fed for high (H) or moderate (M) liveweight gain for 10 days prior to insemination (P1; first letter), and for moderate (M) liveweight gain or for liveweight loss (L) for the first 93 days of pregnancy (P2; second letter) during Experiment 2.1.

	Treatment group				Significance [3 4]					
	HM	HL	MM	ML	P1	P2	P1xP2	Day[1]	P1xP2 xDay	Assist-ance[2]
Live weight										
$n_{pregnancy}$	16	15	19	21						
D-10[3]	340 ± 10^{b}	357 ± 10^{a}	341 ± 9^{b}	346 ± 9^{ab}	***	***	***	***	***	
D-2[3]	350 ± 10^{ab}	366 ± 10^{a}	346 ± 10^{b}	350 ± 9^{b}						
D93[3]	402 ± 10^{a}	356 ± 10^{b}	399 ± 10^{a}	336 ± 9^{c}						
D268[3]	497 ± 11^{a}	408 ± 11^{b}	491 ± 10^{a}	402 ± 10^{b}						
Pre-partum	503 ± 12^{a}	438 ± 12^{b}	506 ± 11^{a}	432 ± 11^{b}	n.s.	***	n.s.			
Post-partum	432 ± 10^{a}	380 ± 11^{b}	434 ± 10^{a}	369 ± 10^{b}	n.s.	***	n.s.			0.078
$n_{lactation}$	16	13	16	16						
L89[4]	530 ± 12^{a}	489 ± 13^{b}	528 ± 12^{a}	484 ± 12^{b}	n.s.	***	n.s.	***	n.s.	*
L155[4]	505 ± 12^{a}	477 ± 12^{b}	511 ± 16^{a}	473 ± 12^{b}						
L208[4]	493 ± 12^{ab}	475 ± 12^{bc}	501 ± 12^{a}	466 ± 12^{c}						
Body condition score										
Pre-partum	2.9 ± 0.1^{ab}	2.6 ± 0.1^{bc}	3.2 ± 0.1^{a}	2.5 ± 0.1^{c}	n.s.	***	n.s.			

[1] Day of measurement

[2] Assistance administered to the heifer at parturition (binomial trait).

[3, 4] For variables analysed as repeated measures ([3] live weight during pregnancy, [4] live weight during lactation), significance values apply across all variables within a model.

[a, b, c] Values within rows with different superscripts differ at the $P<0.05$ level.

n.s. = not significant, $P>0.1$; * $P<0.05$; ** $P<0.01$; *** $P<0.001$

Maternal plasma progesterone concentrations were greater in the MM group than in the ML group on D13 of pregnancy (11.2 ± 1.5 ng/ml versus 7.5 ± 1.1 ng/ml; $P<0.05$), but there were no differences among treatments on D42 or D93 (data not shown). Within treatment, the only significant change over time in maternal plasma progesterone concentration was an increase ($P<0.05$) from 7.5 ± 1.1 ng/ml to 10.3 ± 0.8 ng/ml between D13 and D42 for the ML treatment. The estimate of repeatability of maternal plasma progesterone concentration was 42%. Birth weight of the calf was not correlated with maternal plasma progesterone concentration on D13, D42 or D93 (data not shown).

Placentae

There were no differences among treatments in total weight of placenta, total or mean weight of cotyledons, weight of membranes or number of cotyledons (data not shown). Weight of placenta, total weight of cotyledons, mean weight of cotyledons, and weight of fetal membranes were positively correlated with birth weight irrespective of treatments (Table 6.3), but there was no correlation between birth weight and number of cotyledons.

Table 6.3. Correlations between birth weight of calves, total weight of placenta, total weight of cotyledons, mean weight of cotyledons, weight of membranes and number of cotyledons from primiparous Angus heifers pooled across four liveweight gain treatment groups.

	n	Total weight of placenta	Total weight of cotyledons	Mean weight of cotyledons	Weight of membranes	Number of cotyledons
Birth weight	31	0.54^{**}	0.66^{***}	0.36^{*}	0.41^{*}	$0.17^{n.s.}$
Total weight of placenta	31		0.79^{***}	$-0.01^{n.s.}$	0.90^{***}	0.60^{***}
Total weight of cotyledons	31			$0.21^{n.s.}$	0.65^{***}	0.58^{***}
Mean weight of cotyledons	31				$-0.13^{n.s.}$	-0.63^{***}
Weight of membranes	29					0.58^{**}

n.s. = not significant, $P>0.1$; * $P<0.05$; ** $P<0.01$; *** $P<0.001$

Calves

The heaviest calves were born to HM and MM heifers and the lightest calves were born to HL heifers ($P<0.05$; Table 6.4). When adjusted for maternal post-partum live weight, calves born to HL heifers were lighter ($P<0.05$) than calves born to HM, MM and ML heifers, whose calves were not different to each other. Male calves were heavier than female calves, regardless of whether adjustment for maternal live weight was made.

Body dimensions of calves, adjusted to a common birth weight, were largely unaffected by maternal liveweight gain treatment (Table 6.6), with the exceptions of: depth of shoulders, which was lesser for calves born to ML heifers compared with calves born to heifers in the other liveweight gain treatments; and height at withers, which was lesser for the HL calves compared with the HM and MM calves. All body dimensions were related to birth weight of the calf except distance between the top of the left and right scapulae.

Estimated milk intake of the calves was lower for ML calves compared with MM calves at 40 days of age ($P<0.05$), but there were no other differences in estimated milk intake (Table 6.5). The estimate of repeatability of milk intake was 36%. Female calves had lower estimated milk intake than male calves. Estimated milk intake at 40, 60 and 89 days of age was positively correlated with live weight at each time point measured between birth to L208 ($P<0.05$; data not shown).

Of those calves that were reared to weaning, HL calves were lighter at birth than HM and MM calves ($P<0.05$; Table 6.7). By 40 days of age, ML calves were lighter ($P<0.05$) than HM and MM calves, and HL calves remained lighter than the MM calves but were no longer different to the HM calves. These differences persisted until L208. Mean daily liveweight gain from birth to L208 was 0.94 ± 0.03, 0.96 ± 0.03, 0.90 ± 0.03, and 0.99 ± 0.03 kg/day for the HL, HM, ML and MM treatments, respectively. Rate of gain of MM calves was greater than for ML calves ($P<0.05$).

At 16 months of age, female calves born to heifers in the HL and ML treatments did not differ in liveweight (354 ± 10 kg and 355 ± 10 kg, respectively) but were both lighter ($P<0.001$) than female calves born to heifers in the HM and MM treatments, which were similar in live weight (385 ± 10 kg and 392 ± 10 kg, respectively).

Table 6.4. LSM ± s.e. for birth weight (kg) with and without adjustment for post-partum live weight (PPLW) of the heifer for calves born to heifers fed for high (H) or moderate (M) liveweight gain for 10 days prior to insemination (P1; first letter), and for moderate (M) liveweight gain or for liveweight loss (L) for the first 93 days of pregnancy (P2; second letter).

	Treatment				Significance				
	HM	HL	MM	ML	P1	P2	P1 x P2	Sex	PPLW
n	16	15	19	21					
Birth weight	35.9 ± 1.2[a]	30.7 ± 1.3[c]	36.3 ± 1.2[a]	33.4 ± 1.2[b]	0.076	***	n.s.	*	
Birth weight adjusted for PPLW	35.1 ± 1.3[a]	31.0 ± 1.3[b]	35.4 ± 1.3[a]	34.2 ± 1.2[a]	0.051	*	n.s.	*	0.074

[a, b, c] Values within rows with different superscripts differ at the P<0.05 level.
n.s. = not significant, P>0.1; * P<0.05; ** P<0.01; *** P<0.001

Table 6.5. LSM ± s.e. for estimated milk intake (kg/day) at 40, 60 and 89 days of age of calves born to heifers fed for high (H) or moderate (M) liveweight gain for 10 days prior to insemination (P1; first letter), and for moderate (M) liveweight gain or for liveweight loss (L) for the first 93 days of pregnancy (P2; second letter).

	Treatment group			
	HM	HL	MM	ML
n	16	13	16	16
Day 40[1]	6.5 ± 0.6[ab]	5.7 ± 0.7[ab]	7.1 ± 0.6[a]	5.7 ± 0.6[b]
Day 60[2]	6.2 ± 0.6[ab]	6.4 ± 0.6[ab]	6.7 ± 0.6[ab]	6.3 ± 0.6[ab]
Day 89[2]	6.2 ± 0.7[ab]	5.8 ± 0.8[ab]	6.8 ± 0.8[ab]	5.5 ± 0.8[ab]
Significance	Period 1 [n.s.]		Period 2 [*]	
	Date of birth of calf [n.s.]		Sex of calf [*]	
	Day of measurement x Period 1 x Period 2 [n.s.]			

[1] Number of records for this trait was 10 for HL, 15 for ML and 14 for MM.
[2] Number of records for this trait was 15 for HM.
[a, b] Values with different superscripts differ at the P<0.05 level.
n.s. = not significant, P>0.1; * P<0.05; ** P<0.01; *** P<0.001

Table 6.6. LSM ± s.e. for body dimensions (cm) adjusted for birth weight (BWT) of calves born to heifers fed for high (H) or moderate (M) liveweight gain for 10 days prior to insemination (P1; first letter), and for moderate (M) liveweight gain or for liveweight loss (L) for the first 93 days of pregnancy (P2; second letter).

	Treatment group				Significance				
	HM	HL	MM	ML	P1	P2	P1 x P2	Sex	BWT
n	16	13	16	16					
Body length	81.7 ± 1.3	81.6 ± 1.4	81.8 ± 1.3	82.7 ± 1.3	n.s.	n.s.	n.s.	n.s.	***
Thoracic girth[1]	73.1 ± 0.4	73.3 ± 0.5	72.9 ± 0.4	72.4 ± 0.4	n.s.	n.s.	n.s.	0.099	***
Circumference of head	46.3 ± 0.4	46.6 ± 0.4	47.1 ± 0.4	46.8 ± 0.3	n.s.	n.s.	n.s.	n.s.	***
Width of hips	19.2 ± 0.2	19.4 ± 0.2	19.3 ± 0.2	19.4 ± 0.2	n.s.	n.s.	n.s.	n.s.	***
Width of shoulders	18.4 ± 0.2	18.7 ± 0.3	18.8 ± 0.2	18.7 ± 0.2	n.s.	n.s.	n.s.	0.061	***
Depth of shoulders[1]	29.7 ± 0.3[a]	29.8 ± 0.3[a]	29.6 ± 0.3[a]	28.7 ± 0.3[b]	*	n.s.	0.058	n.s.	***
Distance between top of left and right scapula[1]	3.3 ± 0.2	3.1 ± 0.2	3.5 ± 0.2	3.4 ± 0.2	n.s.	n.s.	n.s.	n.s.	0.064
Distance from top of scapula to greater tubercle of humerus	25.7 ± 0.4	25.3 ± 0.4	25.5 ± 0.4	25.6 ± 0.3	n.s.	n.s.	n.s.	n.s.	***
Height at withers	65.2 ± 0.6[a]	63.5 ± 0.7[b]	65.6 ± 0.6[a]	64.7 ± 0.6[ab]	0.074	*	n.s.	n.s.	***
Mean length of forelimb cannon bones	17.4 ± 0.2	16.9 ± 0.3	17.1 ± 0.2	17.0 ± 0.2	n.s.	n.s.	n.s.	n.s.	**
Mean circumference of forelimb cannon bones	12.0 ± 0.2	11.9 ± 0.2	11.9 ± 0.2	11.8 ± 0.2	n.s.	n.s.	n.s.	***	***

[1] Number of records in HM treatment was 15 for these traits.
[a, b] Values within rows with different superscripts differ at the $P<0.05$ level.
n.s. = not significant, $P>0.1$; * $P<0.05$; ** $P<0.01$; *** $P<0.001$

Experiment 2.2

There were no differences in live weight of the heifers at any stage during their second pregnancy or lactation (data not shown). There were no differences among treatments in days to calving, inter-calving interval or in pregnancy rate to one insemination at pregnancy diagnosis to detect third pregnancies (data not shown). Heifers from the HL and HM treatments gave birth to lighter (P<0.05) calves at second calving than heifers in the MM treatment (Table 6.7). Calves born to HL heifers were lighter (P<0.05) than calves born to ML or MM heifers at 63 and 132 days of age.

Table 6.7. LSM ± s.e. for live weight (kg) at birth (0 days) and at mean age of 40, 60, 89, 155, 182 and 208 days for calves that survived to 208 days of age in Experiment 2.1, and live weight at birth and at mean age of 63 and 132 days for calves that survived to 132 days in Experiment 2.2. Calves were born to heifers fed for high (H) or moderate (M) liveweight gain for 10 days prior to insemination (P1; first letter), and for moderate (M) liveweight gain or liveweight loss (L) for the first 93 days of their first pregnancy (P2; second letter).

	Treatment group				Significance[1]
Age	HM	HL	MM	ML	
Exp. 1					
n	16	13	16	16	
0	37 ± 2[a]	31 ± 2[b]	37 ± 2[a]	34 ± 2[ab]	P2 ***
40[2]	68 ± 3[ab]	64 ± 3[bc]	71 ± 3[a]	62 ± 3[c]	P1 x P2 **
60	89 ± 3[ab]	83 ± 3[bc]	93 ± 3[a]	79 ± 3[c]	Day[5] ***
89	119 ± 4[ab]	111 ± 4[bc]	124 ± 4[a]	107 ± 4[c]	Day[5] x P1 x P2 *
155[3]	183 ± 5[ab]	175 ± 6[bc]	194 ± 5[a]	169 ± 5[c]	Date of birth *
182[3]	213 ± 6[ab]	204 ± 6[bc]	225 ± 6[a]	198 ± 6[c]	Sex of calf *
208[4]	236 ± 6[ab]	227 ± 7[bc]	245 ± 6[a]	219 ± 6[c]	Management herd *
Exp.2					
n	10	8	9	10	
0	35.5 ± 1.4[b]	35.2 ± 1.6[b]	40.5 ± 1.5[a]	38.9 ± 1.4[ab]	P1 ***
63	111 ± 4[ab]	101 ± 5[b]	117 ± 4[a]	115 ± 4[a]	P2 *
132	180 ± 5[ab]	168 ± 6[b]	191 ± 5[a]	184 ± 5[a]	Day[5] ***

[1] Significance levels apply to all live weights within experiments.
[2] Number of records for this trait was 12 for HL, 15 for HM and 14 for MM.
[3] Number of records for these traits was 15 for ML.
[4] Number of records for this trait was 14 for ML.
[5] Day of measurement.
[a, b, c] Values within experiments with different superscripts differ at the P<0.05 level.
n.s. = not significant, P>0.1; * P<0.05; ** P<0.01; *** P<0.001

Discussion

The primary aim of these experiments was to examine the effect of maternal liveweight gain prior to insemination and in early pregnancy on birth weight of the calf relative to maternal live weight, and on body dimensions of the calves, as these factors may have a role in dystocia in beef heifers (Priest *et al.* 1998; Cumming 1999). Liveweight gain treatments were successfully applied prior to insemination and for the first trimester of pregnancy. HL and ML heifers grew slower than targeted (and slower than the HM and MM heifers) during the second and third trimesters of pregnancy.

These liveweight gain treatments affected both birth weight of the calves and post-partum live weight of the heifers. The heavier HM and MM heifers produced heavier calves than the lighter ML and HL heifers. Birth weight of calves was similar for the HM, MM and ML groups when adjusted for post-partum liveweight of the heifers, and was greater for these groups than for the HL group. Total liveweight gain during pregnancy was similar for the ML and HL heifers, yet the HL heifers produced lighter calves. Pleasants and Barton (1987) and Chapter 5 reported that birth weight of calves was not affected by variation in liveweight gain during pregnancy if total liveweight gain over the period was similar between treatments. The HL and ML heifers differed only in liveweight gain during the 10 days prior to insemination, indicating that high compared with moderate liveweight gain during this period may have contributed to a reduction in birth weight of the calf. This occurred in spite of the similarities in placental parameters among treatments.

The positive correlations between placental parameters and birth weight of the calf reinforce previous findings of a positive relationship between birth weight and placental weight (Echternkamp 1993). These findings indicate that methods of reducing placental size and development may offer a means of reducing birth weight of the calf, but the treatments in this experiment did not influence placental size.

Furthermore, maternal plasma progesterone has been shown to be positively related to fetal weight in sheep and elongation of the conceptus in cattle (Kleemann *et al.* 2001; Carter *et al.* 2008), and is also inversely related to maternal feeding level in ewes (Parr 1992). There were no such effects in this experiment, with the only difference in maternal plasma progesterone concentration occurring on D13, when the ML heifers had less plasma progesterone than the MM heifers. Whilst the ML heifers delivered calves that were lighter at birth than those born to MM heifers, the HL heifers delivered calves that were lighter still, and this was not reflected in their plasma progesterone concentration.

In agreement with previous research (Prior and Laster 1979; Bellows *et al.* 1982; Chapter 5), different rates of maternal liveweight gain during pregnancy did not influence the body dimensions of calves relative to their birth weight. Furthermore, there is substantial evidence indicating that body dimensions of calves are not important determinants of dystocia, at least within relatively conservative ranges (Nugent and Notter 1991; Nugent *et al.* 1991).

Any benefit in terms of dystocia of the treatments applied in these experiments is limited to a reduction in birth weight relative to post-partum live weight of the heifers in the HL group. This significant reduction in birth weight relative to maternal live weight is likely to have induced a reduction in dystocia amongst these heifers; however, differences in the incidence of dystocia were unlikely to be detected using few heifers because of the binomial distribution of the trait. Nevertheless, the potential benefits to dystocia of this 3–4 kg (8–15%) reduction in birth weight are significant, and consideration of the longer-term implications of the treatment is warranted. A 3 kg difference in birth weight would require a 6 kg difference in the EBV for birth weight of the sire; in light of the 5.1 kg difference between the EBV of the best and worst 5% of 2006-born Angus calves for birth weight (New Zealand Angus Association 2008), such a difference could be difficult to achieve using genetics alone.

Estimated milk intake of the calves and, by inference, milk yield of the heifers (Barton 1970), was largely unaffected by treatment, in spite of the greater growth rates of the HL and ML heifers during lactation. Thus, heifers in the HL and ML treatments were able to exhibit compensatory liveweight gain during lactation, without this inhibiting milk production. Estimated milk intake of the calves in this experiment was consistent with previous reports of calves born to two-year-old Angus heifers grazing at Massey University's Tuapaka farm (Pleasants and Barton 1987; Chapter 5). Estimated milk intake at 40, 60 and 89 days of age was correlated with liveweight gain of the calves across treatments at all ages measured, in agreement with Barton (1970) but in contrast to Chapter 5, in which there were no correlations between estimated milk intake and live weight at these ages.

Although the difference between the live weight of calves from the HM and LM group, compared with calves from the HL and ML group was not significant during the rearing period, the difference persisted until 16 months of age, at which time it reached significance. This indicates that although these treatments had some success in reducing the birth weight of the calves, there were long term repercussions for their growth. This long term impact of the treatments on the growth of the progeny may negate the benefits of the reduced birth weight of the calves.

The similar rebreeding performance and subsequent live weights among treatments through to weaning of the second calf indicate that the level of feeding or liveweight gain during first pregnancy did not have a lasting impact on these parameters, at least within the rates considered here. The similarities among treatments in inter-calving interval and days to calving indicated that post-partum anoestrus interval was unlikely to have been affected, although it was not measured in this study. These results should be interpreted with some caution, as Experiment 2.2 involved few heifers per treatment.

The second calves of heifers from the HL treatments were lighter than expected. Potentially, the treatments imposed in the Experiment 2.1 may have had a lasting impact on the maternal capacity of the heifers, however, there seems to be no obvious mechanism for this. An alternative possibility may be that the random allocation of heifers to the treatments resulted in the HL group containing heifers with genes for lesser birth weight than the other groups. Birth weight is highly heritable (0.40 – 0.45, Holland and Odde 1992), so genetic factors may have contributed to the HL heifers producing lighter calves in both experiments, although this is unlikely to fully explain the differences observed. Further research is required to determine whether these effects are repeatable in other heifers.

Conclusion

The liveweight gain treatments applied in this experiment offered some potential for manipulating the birth weight of calves, with the desirable reduction in birth weight of the calf relative to post-partum live weight of the heifer observed for heifers fed for high liveweight gain in the 10 days prior to conception then for liveweight loss during the first trimester of pregnancy (HL). The delivery of light second calves by the HL heifers raises questions regarding the lasting impact of the treatments, or the genetic similarity of the heifers in the HL group. Generally, calves that were lighter at birth were lighter during the calf rearing period, and these female calves were substantially lighter than female calves that were heavier at birth at 16 months of age. Liveweight gain of heifers during pregnancy did not affect the milk intake of the calves or the rebreeding performance of the heifers. Further research is justified to determine the repeatability of the HL treatment in generating lighter calves and refine the period in which it could be applied to elicit the desired birthweight response.

Implications

The HL treatment applied in this experiment showed some promise for effecting a reduction in birth weight of the calf relative to live weight of the heifer. If it could be induced reliably, the approximately 10% reduction in birth weight observed is likely to have substantial benefit to incidence of dystocia in heifers. The prolonged period of liveweight loss imposed in this experiment had detrimental effects on the heifers, however, and for this reason such a treatment would encounter some resistance from industry. Further research to examine the repeatability of the effect of the treatment, and to determine whether a similar effect could be achieved with a shorter period of liveweight loss is reported in Chapter 7.

CHAPTER 7

Effects of liveweight gain of 15-month-old Angus heifers during the first trimester of pregnancy on live weight and milk intake of their calves

Publications arising from this chapter:

Hickson RE, Kenyon PR, Lopez-Villalobos N, Morris ST.
Effects of liveweight gain of 15-month-old Angus heifers during the first trimester of pregnancy on live weight and milk intake of their calves
New Zealand Journal of Agricultural Research 52, 39-46, 2009

Abstract

Nutritional methods of manipulating birth weight of calves would be beneficial for managing dystocia in beef heifers. Sixty-five 15-month-old Angus heifers were managed under the following liveweight gain treatments for the first 42 days and then from 42 to 90 days of pregnancy: treatment 1: high liveweight gain throughout (881 ± 59 g/day and 212 ± 45 g/day); treatment 2: low liveweight gain throughout (182 ± 60 g/day and -565 ± 47 g/day); and treatment 3: low then high liveweight gain (217 ± 59 g/day and 379 ± 44 g/day). Heifers were managed in one herd from day 90 of pregnancy until parturition. Birth weight of calves was not affected by treatment, and was 32.3 ± 0.9 kg, 32.9 ± 0.9 kg and 32.5 ± 0.9 kg for treatment 1, 2 and 3, respectively. Calves born to heifers in treatment 2 consumed less milk at 90 days of age than calves from heifers in the other treatments ($P<0.05$). Liveweight gain restriction in the first trimester of pregnancy did not reduce birth weight of calves and, therefore, could not be used to manage dystocia in heifers.

Introduction

It would be of substantial value to the beef cattle industry in New Zealand if heifers routinely calved for the first time at two years of age, without the increased incidence in dystocia that frequently occurs in two-year-old beef heifers. Dystocia is one factor deterring farmers from calving heifers at two instead of the traditional three years of age, in spite of the documented gains in efficiency and productivity that could be achieved (Carter and Cox 1973; Parminter *et al.* 1993; Chapters 2 and 3).

The predominant cause of dystocia in two-year-old beef heifers is feto-maternal disproportion, a condition that could be alleviated by reducing the birth weight of the calf relative to the live weight of the heifer (Rice 1994). There has been much research examining the effects of liveweight gain of heifers in the last 2-3 months of pregnancy on birth weight of the calves, but this has proved to be ineffective for managing dystocia, and calves born to heifers that had restricted liveweight gain in late pregnancy were sometimes lighter at weaning (Kroker and Cummins 1979). Industry interest in the effects of liveweight gain of heifers in early pregnancy on birth weight of the calf has increased in New Zealand in recent years, but to date there has been little investigation into this. Retrospective analysis reported that there was a negative correlation between birth weight of calves and liveweight gain of mature Angus cows around one month after conception (Morris *et al.* 2004). An experiment examining low versus moderate liveweight gain of heifers in the first 93 days of pregnancy showed no difference in the birth weight or weaning weight of the calves (Chapter 5).

A recent experiment showed that heifers that had high liveweight gain for ten days prior to insemination and lost weight during the first trimester of pregnancy delivered calves that were lighter absolutely and relative to maternal live weight than those born to heifers that had moderate liveweight gain for ten days prior to insemination and lost weight during the first trimester of pregnancy, or high or moderate liveweight gain prior to insemination and moderate liveweight gain during the first trimester of pregnancy (Chapter 6). In that experiment, the calves that were lighter at birth remained lighter at 16 months of age than the calves that were heavier at birth. An additional negative consequence of the liveweight gain restrictions imposed on these heifers was that heifers were lighter than desirable at calving. Nevertheless, the reduction in birth weight observed in that experiment has the potential to have a significant impact on the incidence of dystocia in two-year-old heifers, and warrants further investigation.

The primary aim of this experiment was to determine whether changing the rate of liveweight gain of heifers from high to low on day of insemination until day 90 of pregnancy is a means of reducing birth weight of calves, and whether this could be achieved with 42 instead of 90 days of low liveweight gain. The secondary aim of the experiment was to determine the impact of these liveweight gain treatments on milk intake or live weight of the calves.

Materials and methods

Animals and treatments

Oestrus was synchronised in 150 15-month-old Angus heifers using the procedure detailed in Chapter 5. All heifers were inseminated with semen from one of four Angus bulls 48–52 h after removal of the progesterone-primed controlled internal drug release device. Service sires were selected that had an EBV for birth weight between +1.9 and +3.5 kg (minimum accuracy 68%; these EBVs placed the bulls in the 5-30th percentile for 2006-born Angus calves) and an EBV for direct calving ease of greater than +1.8% (n=2; minimum accuracy 55%; top 15% of 2006-born Angus calves) or less than -1.9% (n=2; minimum accuracy 67%; bottom 15% of 2006-born Angus calves).

Pregnancy was detected using rectal palpation 42 days after the first insemination (D42) and heifers that were diagnosed non-pregnant to first insemination (n=82) were excluded from the experiment. Two heifers diagnosed pregnant on D42 did not produce a calf at term and one heifer was observed to abort her pregnancy on D225, and these heifers were also excluded from the experiment.

All heifers were managed to achieve high liveweight gain (target 750 g/day) during the 10 days prior to insemination (D-10 to D0), then heifers were allocated to one of three treatment groups balanced for initial live weight, service sire and herd of origin (seven source herds, all heifers had been grazing at the research unit for a minimum of one month prior to the start of the experiment). Treatments were: 1. high liveweight gain (target 750 g/day) for the first trimester (D0 to D90) of pregnancy; 2. low liveweight gain (target 100 g/day) from D0 to D90; and 3. low liveweight gain from D0 to D42 followed by high liveweight gain from D42 to D90. All heifers were grazed in one herd from D90 until parturition. The number of heifers that calved was 22, 20 and 23 for treatments 1, 2 and 3, respectively.

Heifers were observed from D274 until parturition at least every four hours between 0645 and 2300, and were left unsupervised between 2300 and 0645. If a heifer was observed to be in labour during any observation period, the frequency of observation was increased until the calf was born. Assistance was provided at the discretion of experienced herdsmen, using the guidelines that heifers were allowed four hours of parturition before assistance was administered in cases of a normal presentation, but that assistance could be administered as soon as fetal malpresentation was detected. Assistance was provided by the herdsmen in the first instance, and veterinary assistance was available where necessary.

Three calves were stillborn as a result of dystocia and five calves died within two weeks of birth, due to disease (n=1), starvation exposure as a result of limited mobility caused by contracted tendons and blindness (n=1), mismothering (n=2) or misadventure (n=1). Dams of these calves were excluded from all post-partum records except the post-partum live weight recorded within 24 hours of parturition.

From day of parturition until weaning (D438), heifers with live calves were grazed in two herds; one of early- and one of late-calving heifers; but both herds were under the same commercial management at all times. Two inexperienced 15-month-old Angus bulls were joined with each herd from D355 to D396. Male calves were castrated on D321.

Measurements

Heifers

Unfasted live weight was recorded on D-10, D-1, D2, D19, D36, D42, D64, D88, D109, D134, D159, D194, D225, D239, and D267. Further unfasted live weights were recorded within 24 h of parturition, on D321, D341, D371, D396 and D438. Pregnancy to rebreeding was detected using rectal palpation on D438. Every parturition was classified as assisted or non-assisted. In cases where fetal malpresentation had contributed to the dystocia, this was noted.

Calves

All calves were weighed within 24 hours of birth, and sex of calf was recorded. Additionally, body length, height at withers, depth of shoulders (from the withers to the breast bone), circumference of head, width of shoulders, thoracic girth, width of hips, and length and girth of left and right forelimb cannon bones were recorded on live calves (Nugent *et al.* 1991). Crown-rump length and the distance between the top of the left scapula and the top of the greater tubercle of the left humerus were also recorded. Calves were standing upright while these measurements were made. Body dimensions were not made on one calf with contracted tendons on its front limbs that was unable to stand upright.

Fasted live weight was recorded on D321, D341 and D371 (mean age 40, 60 and 90 days). Unfasted live weight was recorded on D396 and D438 (mean age 115 and 157 days). Milk intake of the calves was assessed on D321, D341 and D371 using the weigh-nurse-weigh technique (Barton 1970).

Statistical methods

Data were analysed using the Statistical Analysis System (SAS version 9.1, SAS Institute Inc., Cary, NC, USA, 2003). Live weights from D-10 until D267 were analysed using a linear model in the MIXED procedure with treatment, sex of calf, day of gestation and treatment-by-day of gestation interaction fitted as fixed effects. The random effects of farm of origin, service sire and the random effect of heifer to allow for repeated measures were considered. Similarly, average daily liveweight gain was analysed using linear models in the MIXED procedure with treatment fitted as a fixed effect. Farm of origin was fitted as a random effect. Live weights from calving to weaning were analysed using a linear model in the MIXED procedure with treatment, assistance at calving (binomial trait), day of experiment and the interaction of day of experiment with treatment as fixed effects, and farm of origin of heifer and heifer as random effects to allow for repeated measures. Pregnancy rate on D438 was analysed as a binomial trait using a logistic regression model with the GENMOD procedure. Treatment and assistance at first parturition were considered as fixed effects. Incidence of assistance at parturition was analysed as a binomial trait using a logistic regression model with the GENMOD procedure and treatment considered as a fixed effect.

Birth weight of the calf was analysed using a linear model in the MIXED procedure, with treatment and sex of calf as fixed effects and sire as a random effect. Gestation length and the interaction of sex of calf with gestation length were considered but excluded from the model as their effects were not significant. Models were run with and without post-partum live weight of the heifer as a covariable. Linear models within the MIXED procedure were used for body dimensions, with birth weight of the calf as a covariable and treatment and sex of calf as fixed effects. Sire was fitted as a random effect.

Milk intake of calves was analysed using a linear model for repeated measures within the MIXED procedure. Fixed effects were sex of calf, treatment, day of age, treatment by day interaction, assistance at birth and assistance by day of age interaction. Sire and calf were fitted as random effects. Date of birth of calf was fitted as a covariable but did not explain a significant amount of variation and was removed from the model. Similarly, live weights of calves from birth to weaning were considered as repeated measures using a similar model as for milk intake, although date of birth of calf was significant in this model. Grazing herd was considered as a random effect for milk intake and live weight of calves.

The contribution of birthweight-adjusted body dimensions to the probability of assistance at parturition was explored using the LOGISTIC procedure, with non-significant effects removed from the model. Body dimensions were adjusted for birth weight using linear models in the GLM procedure, and the residual body dimensions were fitted in the logistic regression model. Sire of calf was considered as a contributor to the probability of assistance at parturition, but was excluded from the model because it had no significant effect.

Results

Heifers

Nutritional treatments were applied in the first trimester of pregnancy so that a significant difference in the rate of liveweight gain amongst the groups was achieved (Table 7.1). Rates of liveweight gain differed from targeted rates in some periods, particularly D42 to D88, however, the differences between the treatments were consistent with the target differences. Heifers in treatment 1 were heavier than heifers in the other treatments by D42 and this difference remained until D267. There were no differences in liveweight of the heifers among treatments from day of parturition until D438.

Sixteen heifers were assisted at parturition and fetal malpresentation was a contributing factor in four of these cases. There were no differences among treatments in the proportion of heifers assisted (data not shown), but numbers were too low for detecting differences for this binomial trait. Heifers that were assisted were lighter ($P<0.05$) throughout their calf-rearing period than heifers that were not assisted (364 ± 11 kg versus 399 ± 9 kg post-partum and 387 ± 11 kg versus 425 ± 9 kg at weaning), but there was no difference in the growth rate of these heifers from parturition to weaning (170 ± 20 g/day compared with 159 ± 40 g/day for non-assisted and assisted heifers, respectively). Pregnancy rates to rebreeding were not different among the treatments, or between assisted and non-assisted heifers (data not shown), however, the experiment had limited power to detect differences as pregnancy status was also a binomial trait.

Calves

Birth weight of calves was not affected by the liveweight gain treatments of the heifers (32.3 ± 0.9 kg, 32.9 ± 0.9 kg and 32.5 ± 0.9 kg for treatments 1, 2 and 3, respectively). Similarly, there were no differences among treatments in birth weight with adjustment for post-partum liveweight of the heifer (data not shown). Generally, body dimensions of calves were not affected by treatment (Table 7.2). All body dimensions were related to birth weight.

Table 7.1. LSM ± s.e. daily liveweight gains (g/day) and live weights (kg) of heifers fed for high liveweight gain from D0 to D90 of pregnancy (1), low liveweight gain from D0 to D90 of pregnancy (2), or low liveweight gain from D0 to D42 of pregnancy and high liveweight gain from D42 to D90 of pregnancy (3).

	Treatment			Significance[1]
	1	2	3	
Live weight gain				
D-10 to D-1	721 ± 211	752 ± 219	545 ± 208	Treatment[n.s.]
D2 to D42	881 ± 59[a]	182 ± 60[b]	217 ± 59[b]	Treatment***
D42 to D88[2]	212 ± 45[b]	-565 ± 47[c]	379 ± 44[a]	Treatment***
D88 to D267	194 ± 19[c]	505 ± 20[a]	327 ± 19[b]	Treatment***
Live weight				
n	22	20	23	
D-10	367 ± 10	366 ± 10	361 ± 10	
D-1	373 ± 10	373 ± 10	366 ± 10	Treatment***
D42	407 ± 10[a]	364 ± 10[b]	359 ± 10[b]	Day***
D88	416 ± 10[a]	338 ± 10[c]	377 ± 10[b]	Treatment x day***
D267	450 ± 11[a]	427 ± 11[b]	435 ± 11[b]	
n	18	17	18	
Post-partum	387 ± 10	374 ± 10	384 ± 10	Treatment***
D341	472 ± 11	458 ± 11	455 ± 11	Day***
D438	412 ± 11	404 ± 10	401 ± 11	Assistance***

[1] Significance values are pooled for the repeated measures analysis of live weight prior to parturition (D-10 to D267), and pooled for live weight during lactation (post-partum to D438).
[2] Cows were weighed on D88, but pasture allowance was not changed until D90, so although the rate of liveweight gain calculated is for D42 to D88, a similar rate is likely to have occurred for D88 to D90.
[a, b, c] Values within rows with different superscripts differ at the P<0.05 level.
n.s. = not significant, * P<0.05, ** P<0.01, *** P<0.001.

Table 7.2. LSM ± s.e. for body dimensions (cm) of calves born to heifers fed for high liveweight gain from D0 to D90 of pregnancy (1), low liveweight gain from D0 to D90 of pregnancy (2), or low liveweight gain from D0 to D42 of pregnancy and high liveweight gain from D42 to D90 of pregnancy (3).

	Treatment			Significance		
	1	2	3	Birth weight	Treat-ment	Sex
n	20	20	21			
Body length	51.9 ± 0.5	51.8 ± 0.5	51.4 ± 0.5	***	n.s.	n.s.
Crown-rump length	79.7 ± 0.8	79.0 ± 0.8	79.2 ± 0.7	***	n.s.	*
Thoracic girth	71.8 ± 0.4	71.6 ± 0.4	72.2 ± 0.4	***	n.s.	n.s.
Width of shoulders	18.8 ± 0.2	19.0 ± 0.2	18.6 ± 0.2	***	n.s.	*
Depth of shoulders	28.7 ± 0.3	28.4 ± 0.3	30.0 ± 0.3	***	n.s.	n.s.
Scapula to humerus[1]	25.5 ± 0.2	25.5 ± 0.2	25.4 ± 0.2	***	n.s.	n.s.
Circumference of head	46.7 ± 0.3	46.6 ± 0.3	46.9 ± 0.3	***	n.s.	n.s.
Width of hips	19.5 ± 0.2	19.6 ± 0.2	19.4 ± 0.2	***	n.s.	n.s.
Height at withers	50.1 ± 0.7[b]	50.4 ± 0.7[ab]	51.0 ± 0.7[a]	***	n.s.	n.s.
Length of cannon bone[2]	16.5 ± 0.3[b]	16.9 ± 0.3[ab]	17.1 ± 0.3[a]	***	*	n.s.
Circumference of cannon bone[2]	11.6 ± 0.1[a]	11.3 ± 0.1[b]	11.2 ± 0.1[b]	***	*	**

[1] Distance from top of scapula to greater tubercle of humerus
[2] Mean values for both forelimb cannon bones
[a, b] Values within rows with different superscripts differ at the P<0.05 level.
n.s. = not significant, * P<0.05, ** P<0.01, *** P<0.001.

Table 7.3. LSM ± s.e. for live weight (kg) at mean age of 0, 40, 60, 90, 115 and 157 days and milk intake (kg/day) at mean age of 40, 60 and 90 days of calves reared to weaning that were born to heifers fed for high liveweight gain from D0 to D90 of pregnancy (1), low liveweight gain from D0 to D90 of pregnancy (2), or low liveweight gain from D0 to D42 of pregnancy and high liveweight gain from D42 to D90 of pregnancy (3), and for calves reared to weaning that were or were not assisted at birth.

	Treatment			Assisted at birth		Significance[1]
	1	2	3	Yes	No	
Live weight						
n	18	17	18	40	13	
0	34 ± 1	34 ± 1	33 ± 1	36 ± 1[a]	32 ± 1[b]	
40	72 ± 2	68 ± 2	71 ± 2	70 ± 2	70 ± 1	
60	89 ± 2	86 ± 2	90 ± 2	88 ± 3	89 ± 1	Treatment**
90	114 ± 3	111 ± 3	115 ± 3	113 ± 3	114 ± 2	Date of birth* Day***
115	140 ± 3	135 ± 3	144 ± 3	139 ± 4	140 ± 2	
157	160 ± 4[ab]	155 ± 4[b]	166 ± 4[a]	158 ± 5	162 ± 3	
Milk intake						
n	16	15	11	31	11	
40	5.0 ± 0.5[ab]	4.4 ± 0.4[b]	5.8 ± 0.5[a]	5.1 ± 0.5	5.0 ± 0.3	
n	17	17	18	39	13	
60	6.1 ± 0.4	5.1 ± 0.4	5.9 ± 0.4	6.1 ± 0.4	5.3 ± 0.3	Treatment** Day**
n	15	17	18	38	12	
90	5.1 ± 0.5[a]	3.8 ± 0.4[b]	4.9 ± 0.4[a]	4.5 ± 0.5	4.7 ± 0.3	

[1] Significance values are pooled for the repeated measures analysis of live weight, and for the repeated measures analysis of milk intake.

[a, b] Values with different superscripts differ between assisted and non-assisted heifers or amongst treatment groups at the P<0.05 level.

n.s. = not significant, * P<0.05, ** P<0.01, *** P<0.001

Body dimensions did not contribute to the probability that a calf experienced assistance at birth but the probability of assistance increased with increasing birth weight (odds ratio 1.47, [95% CI 1.08–1.99]) and decreased with increasing post-partum live weight of the heifer (0.94, [0.90–0.99]). Male calves were 9.3 times [1.5–58.8 times] more likely than female calves to experience assistance at birth when birth weight was not considered, however, sex of calf made no significant contribution to the probability of assistance if birth weight was included in the model. This indicated that the effect of sex on probability of assistance at birth was explained by greater birth weight of male than female calves (33.9 ± 0.7 versus 31.3 ± 0.8 kg; $P<0.05$).

There were no differences in liveweight of calves among treatments prior to D438 (Table 7.3). At D438, calves born to heifers in treatment 3 were heavier ($P<0.05$) than calves born to heifers in treatment 2. Milk intake of calves was greater ($P<0.05$) for calves born to heifers in treatment 3 than for calves born to heifers in treatment 2 at 40 and 90 days of age. Calves born to heifers in treatment 2 also had lesser milk intake ($P<0.05$) than calves born to heifers in treatment 1 at 90 days of age.

Assisted calves that survived to weaning were heavier at birth ($P<0.05$) than non-assisted calves that survived to weaning, but there were no later differences in live weight.

Discussion

The similarity in birth weight amongst the calves in this experiment indicates that differences in liveweight gain of heifers during early pregnancy did not influence fetal weight, in agreement with Chapter 5 and Prior and Laster (1979) but in contrast to the findings of Morris *et al.* (2004) and Chapter 6. In Chapter 6, calves born to heifers fed for high liveweight gain for 10 days prior to insemination then for liveweight loss for the first 93 days of pregnancy were lighter than calves born to heifers fed for moderate liveweight gain for 10 days prior to insemination and for liveweight loss during the first trimester of pregnancy. The present study indicated that these regimes can not be used to reduce birth weight, and potentially, dystocia in heifers. A potential explanation for this is that the heifer may have some ability to provide a buffer to the conceptus against poor nutrition during this stage of pregnancy, given that the absolute nutrient requirements of the conceptus are very low at this time (Robinson *et al.* 1999).

There is industry concern within New Zealand and Australia that body dimensions of calves, particularly of the shoulders, may affect the incidence of dystocia (Priest *et al.* 1998; Cumming 1999). The treatments considered in the present experiment had no effect on shoulder dimensions of calves, in keeping with the similarity in incidence of assistance at birth. The relevance of these body dimensions to dystocia is questionable, however, as there was no effect of body dimensions on assistance at birth in this or in previous experiments (Nugent and Notter 1991; Nugent *et al.* 1991).

The greater incidence of assistance at birth among male compared with female calves was consistent with previous studies, however, unlike the reports of Lowman (1979), Rutter *et al.* (1983) and Chapter 5, the difference in incidence of assistance at birth could be fully explained by the increased birth weight of the male calves in this experiment, in agreement with Laster *et al.* (1973), Price and Wiltbank (1978), and Sawyer *et al.* (1991).

Despite being heavier at birth, assisted calves were not different from non-assisted calves at any other stage of rearing, in agreement with Chapter 5. This may indicate that assisted calves grew more slowly than their non-assisted counterparts in the first 40 days of life (Meijering 1984), by which time they were no longer affected by their assisted birth and were similar to non-assisted calves for the remainder of the rearing period. The prompt provision of assistance to heifers suffering dystocia at parturition may have also played a role in minimising the impact of the dystocia on the affected heifers and calves. This suggestion is supported by the similarity in pregnancy rate after rebreeding between assisted and non-assisted heifers. In contrast, Laster *et al.* (1973) reported that first-calving two-year-old heifers that experienced dystocia at parturition were less likely to have been detected in oestrus or to have conceived to artificial insemination.

Calves born to heifers in treatment 2 consumed less milk than calves born to heifers in the treatment 3 at 40 and 90 days of age, and less milk than calves born to heifers in treatment 1 at 90 days of age. Milk intake of calves is an indicator of the milk yield of the heifer (Barton 1970). This lesser milk intake of calves (and probable lesser milk yield of heifers) could potentially be a result of those heifers losing liveweight between days 42 and 90 of pregnancy, or of these heifers being lighter throughout gestation. Udder development occurs throughout pregnancy (Swanson and Poffenbarger 1979), and may have been impaired by the liveweight loss treatment imposed on the heifers during this time. Previous experiments showed no effect (Chapter 5) or little effect (Chapter 6) of liveweight gain treatment on milk intake of the calves, but the low liveweight gain and liveweight loss treatments were less extreme in those experiments than in the present experiment. The impact of the lesser milk intake of calves born to heifers in treatment 2 was evident on D438, when those calves were lighter than calves born to heifers in treatment 3. This may impair the subsequent performance of the calves, because calves that were light at weaning may produce light carcasses or take longer than desired to reach slaughter weights (Everitt 1972).

Conclusions

Variable rates of liveweight gain in the first trimester of pregnancy did not affect the birth weight of calves born to primiparous, two-year-old, Angus heifers; hence was not useful for managing dystocia in primiparous beef heifers. The rebreeding performance of heifers was not affected by liveweight gain treatments or assistance at parturition. Calves born to heifers that were fed for low liveweight gain from D0 to D42 of pregnancy and for liveweight loss from D42 to D90 of pregnancy had lesser milk intake and were lighter at weaning than calves born to heifers that were fed for low liveweight gain from D0 to D42 of pregnancy and high liveweight gain from D42 to D90 of pregnancy. Prolonged restricted liveweight gain of the heifer may have negative implications for the performance of the calf from birth until weaning.

Implications

This experiment confirmed that manipulation of the liveweight gain of heifers in the first trimester of pregnancy can not be used to reliably regulate birth weight of the calf. These experiments are complicated by the potential for variation in maternal liveweight gain during the second and third trimesters of pregnancy, which makes it difficult to ascertain whether these treatments affected fetal growth during early gestation. This complication was avoided in Chapter 8 by examining the conceptus at the end of the first trimester of pregnancy.

CHAPTER 8

Size of fetuses and placentae from primiparous, 15-month-old Angus heifers fed for moderate or low liveweight gain for 21 days prior to insemination and for the first trimester of pregnancy

Publications arising from this chapter:

Hickson RE, Kenyon PR, Lopez-Villalobos N, Morris ST.
Short communication: Size of fetuses and placentae from primiparous, 15-month-old, Angus heifers fed for moderate or low liveweight gain for 21 days prior to insemination and for the first trimester of pregnancy.
New Zealand Journal of Agricultural Research 52, 31-7, 2009

Hickson RE, Lopez-Villalobos N, Kenyon PR, Morris ST.
The effect of maternal liveweight gain of 15-month-old beef heifers on foetal weight.
Proceedings of the New Zealand Society of Animal Production 67, 117-20, 2007

Abstract

Two experiments were carried out in which 15-month-old Angus heifers were allocated to a moderate or low liveweight gain treatment from 21 days prior to insemination until day 90 or 91 of gestation. Liveweight gains were 451 ± 32 g/day (n=8) and 118 ± 32 g/day (n=8) in the first experiment and 595 ± 30 g/day (n=9) and 7 ± 23 g/day (n=15) in the second experiment. Weight of fetus per 100 kg maternal live weight was greater in the low compared with the moderate treatments (59 ± 2 and 53 ± 2 g/100 kg versus 47 ± 2 and 45 ± 2 g/100 kg for the first and second experiments, respectively; $P<0.05$). Number and weight of cotyledons and caruncles were not different between treatments. Liveweight gain of 15-month-old Angus heifers had little effect on fetal or placental size.

Introduction

Production of beef-breed calves is more efficient when heifers are bred to calve for the first time at two instead of three years of age (McMillan and McCall 1991). An increased incidence of dystocia in two-year-old beef heifers compared with primiparous three-year-old beef heifers is one factor deterring farmers from breeding beef heifers at 15 months of age in New Zealand (Carter and Cox 1973; Chapter 3). Birth weight of the calf has a major influence on the incidence of dystocia (Philipsson 1976a; Rutter *et al.* 1983; Rice 1994; Arthur *et al.* 2000, Chapters 5 and 7), so methods of regulating birth weights using maternal nutrition may enable the incidence of dystocia in beef breeding heifers to be reduced, and as result, allow an increase in the productivity and efficiency of the beef industry.

The effect of maternal nutrition in late pregnancy on birth weight of calves and the incidence of dystocia in beef breeding heifers has been extensively reviewed (Meijering 1984; Rice 1994) and generally, has minor and inconsistent effects; yet little is known about the effects of maternal nutrition in early pregnancy on bovine fetal and placental growth. Nutrition of adolescent ewes has been shown to alter weight of the fetus (Wallace *et al.* 2005). It is unknown whether a similar effect occurs in adolescent cattle.

The aim of these experiments was to determine the effect of maternal liveweight gain prior to breeding and for the first trimester of pregnancy on weight of the fetus and fetal organs, fetal body dimensions and placental weight in 15-month-old Angus heifers.

Materials and methods

Animals and treatments

In two experiments, two liveweight gain treatments were imposed under pastoral grazing conditions on 15-month-old Angus heifers from 21 days (one oestrous cycle) prior to insemination until day 90 (Experiment 4.2) or day 91 (Experiment 4.1) of pregnancy (end of first trimester). The two treatments consisted of moderate maternal liveweight gain (target 500 g/day) and low maternal liveweight gain (Experiment 4.1: target 100 g/day; Experiment 4.2: target 0 g/day). Liveweight gain was managed by adjusting the herbage allowance of the groups in response to unfasted live weights that were measured at a maximum of monthly intervals throughout the treatment period.

A total of 376 heifers that had already received one insemination were re-syncrhonised according to the procedure described previously (Chapter 5) to stimulate a second synchronised oestrus. For both experiments, D0 was defined as the first day of inseminations at the second synchronised oestrus. Oestrus detection aids (Estrus Alert®, Western Point Incorporated, USA) were applied to the heifers on D-2. Heifers (n=58 Experiment 4.1, n=60 Experiment 4.2) were inseminated to observed oestrus on D0 (Experiment 4.1 & 4.2) or D1 (Experiment 4.2) with semen from Angus bulls (Experiment 4.1: n=5; BeefPac, LIC, Hamilton, New Zealand; Experiment 4.2: n=4). Heifers were excluded from the experiments if they did not show oestrus on D0 (Experiment 4.1 & 4.2) or D1 (Experiment 4.2), or if they were diagnosed non-pregnant using rectal palpation on D43. Heifers were randomly selected from the remaining heifers for inclusion in the experiments (proportion selected was 16/25 for Experiment 4.1 and 24/36 for Experiment 4.2).

Measurements

Unfasted maternal live weights were recorded on D89 (Experiment 4.1) or D88 (Experiment 4.2). At D91 (Experiment 4.1) or D90 (Experiment 4.2), the heifers were slaughtered through a commercial processing plant (AFFCO Manawatu, Feilding, New Zealand). Number of heifers was eight in each treatment for Experiment 4.1, and nine in the moderate and 15 in the low treatment in Experiment 4.2. At slaughter, maternal livers were weighed immediately (Experiment 4.1: with gall bladders on; Experiment 4.2: with gall bladders removed) and gravid uteri were recovered and refrigerated overnight. Carcass weights were provided by the processing plant and dressing out percentage was calculated by dividing hot carcass weight by the live weight recorded on D89 (Experiment 4.1) or D88 (Experiment 4.2).

The following day, excess tissue was trimmed from the uterus before the gravid uterus was weighed intact. The uterus was pierced and drained and the fetus removed. Placentomes were separated and the cotyledons and caruncles were dissected from the fetal and maternal membranes. Weight was recorded of the fluid drained from the uterus and membranes, the fetal membranes (including cotyledons), the empty uterus (including caruncles), the total cotyledons and the total caruncles. Number of cotyledons and number of caruncles were also recorded. Caruncle utilisation was calculated as $\frac{\text{number of cotyledons}}{\text{number of caruncles}} \times 100$. Fetuses were weighed intact and crown-rump length, head circumference, thoracic girth and cannon bone length were measured. Fetal heart, liver, lungs and kidneys were dissected out and weighed wet. In Experiment 4.2, wet weight of fetal spleen, thymus, thyroid glands and adrenal gland was also recorded. Fetal body weight (g) per 100 kg maternal weight was calculated as $\frac{\text{foetal body weight}}{\text{maternal live weight 2 days prior to slaughter}} \times 100$.

Statistical methods

Data were analysed using the MIXED procedure in the Statistical Analysis System (SAS version 9.1, SAS Institute Inc., Cary, NC, USA, 2003). The model for maternal parameters considered the fixed effects of experiment and treatment nested within experiment. Treatments were nested within experiment because the 'moderate' and 'low' treatments varied in the rate of liveweight gain achieved between experiments. Live weight of the heifer two days prior to slaughter was fitted as a covariate for weight of maternal liver to allow comparisons of implied metabolic rate at a constant body weight (Hersom *et al.* 2004). Initial live weight of the heifer (recorded on D-23) was fitted as a covariate in the models for live weight of the heifer two days prior to slaughter, carcass weight of the heifer and dressing out percentage of the heifer. The model for fetal parameters included experiment and treatment nested within experiment as fixed effects, and fetal body weight as a covariate (except in the models for fetal body weight). Sex of fetus as a fixed effect and age of fetus as a covariate were tested and included in the model if they were significant. The model for uterine and placental parameters included the fixed effects of experiment and treatment nested within experiment. Sex of fetus as a fixed effect, age of fetus as a covariate and interactions between sex of fetus and treatment nested within experiment were tested and included in the model if they were significant.

Results

Heifers from the moderate treatment were heavier at slaughter than heifers from the low treatment in both experiments (P<0.001; Table 8.1). Mean initial live weight (D-23) of the heifers that were slaughtered was similar among all treatments. Actual growth rates achieved were 451 ± 32 g/day for the moderate group and 118 ± 32 g/day for the low group in Experiment 4.1 and 595 ± 30 g/day for the moderate group and 7 ± 23 g/day for the low group in Experiment 4.2. Carcass weight and dressing out percentage were greater (P<0.001) in the moderate than the low group in both experiments. Weight of maternal liver was related (P<0.001) to maternal live weight and was greater (P<0.001) in the moderate than the low treatments in both experiments, even with adjustment for maternal live weight.

Fetal body weight not affected by treatment, but fetal weight per 100 kg maternal live weight was greater (P<0.001) in the low compared with the moderate treatment. Male fetuses were heavier than female fetuses. Treatment did not affect body dimensions or the weight of any fetal organ. Body dimensions and most fetal organ weights were related to fetal body weight. There were differences (P<0.05) between experiments in crown-rump length, thoracic girth, head circumference, weight of liver and weight of kidneys.

Number of cotyledons, weight of cotyledons, number of caruncles, weight of caruncles, caruncle utilisation, weight of gravid uterus and weight of maternal membranes did not differ between treatments (Table 3). Weight of fetal membranes tended to be greater (P=0.074) in the low compared with the moderate treatments.

Table 8.1. Live weight, liveweight gain, carcass weight, dressing out percentage and weight of liver on day 91 (Experiment 4.1) or day 90 (Experiment 4.2) of pregnancy of heifers fed for moderate or low rates of liveweight gain from 21 days prior to insemination until slaughter. Rates of liveweight gain were 451 ± 16 versus 118 ± 32 g/day in Experiment 4.1 and 595 ± 30 versus 7 ± 23 g/day in Experiment 4.2, for moderate and low treatments, respectively. Values are LSM ± s.e.

	Experiment 4.1		Experiment 4.2		Significance		
	Moderate	Low	Moderate	Low	Treat-ment	Exp.	LWT[1]
n	8	8	9	15			
Initial live weight (ILW; kg), 21 days prior to insemination	371 ± 13	356 ± 13	383 ± 13	377 ± 10	n.s.	n.s.	
Live weight 2 days prior to slaughter (kg), adjusted for ILW	423 ± 3[b]	385 ± 3[c]	440 ± 3[a]	374 ± 3[d]	***	n.s.	***
Mean daily liveweight gain (g/day)	451 ± 32[b]	118 ± 32[c]	595 ± 30[a]	7 ± 23[d]	***	n.s.	
Weight of liver[2] (kg)	5.0 ± 0.1[b]	4.0 ± 0.1[c]	5.5 ± 0.1[a]	3.8 ± 0.1[d]	***	n.s.	***
Carcass weight (kg) adjusted for ILW	205 ± 2[b]	173 ± 2[c]	210 ± 2[a]	166 ± 1[d]	***	n.s.	***
Dressing out percentage adjusted for ILW	48.5 ± 0.5[a]	44.9 ± 0.5[b]	47.8 ± 0.4[a]	44.3 ± 0.3[b]	***	n.s.	n.s.

[1] LWT refers to initial live weight of the heifer for all variables except weight of maternal liver, in which case live weight refers to live weight of the heifer 2 days prior to slaughter.

[2] Weight of liver included the gall bladder in Experiment 4.1 and excluded the gall bladder in Experiment 4.2. Number of records in the moderate group was 7 for weight of liver in Experiment 4.1.

[a, b, c, d] Values within rows with different superscripts differ at the $P<0.05$ level.

n.s. = not significant, * $P<0.05$, ** $P<0.01$, *** $P<0.001$; missing value indicates that the variable was not fitted.

Table 8.2. Weight of fetus (FWT) and fetal organs and body dimensions of fetus at day 91 (Experiment 4.1) or day 90 (Experiment 4.2) of gestation of fetuses from heifers fed for moderate or low liveweight gain from 21 days prior to insemination until slaughter. Rates of liveweight gain were 451 ± 16 versus 118 ± 32 g/day (Exp. 1) and 595 ± 30 versus 7 ± 23 g/day (Exp. 2) for moderate and low treatments, respectively. Values are LSM ± s.e.

	Experiment 4.1		Experiment 4.2		Significance			
	Moderate	Low	Moderate	Low	Treat-ment	Exp.	FWT	Other
n	8	8	9	15				
Weight (g)								
Fetus	197 ± 6[b]	216 ± 6[a]	202 ± 6	201 ± 5	n.s.	n.s.		sex ***
Fetus per 100 kg maternal live weight	47 ± 2[b]	59 ± 2[a]	45 ± 2[b]	53 ± 2[a]	***	n.s.		sex ***
Heart	1.65 ± 0.07	1.70 ± 0.08	1.57 ± 0.07	1.58 ± 0.05	n.s.	n.s.	**	
Lungs	6.2 ± 0.2	6.0 ± 0.2	6.0 ± 0.2	5.7 ± 0.2	n.s.	n.s.	***	
Liver	9.3 ± 0.5[b]	9.8 ± 0.5[b]	10.0 ±0.5[b]	11.2 ± 0.4[a]	n.s.	*	***	
Kidneys	2.08 ± 0.08[a]	1.93 ± 0.08[b]	1.73 ± 0.07[b]	1.80 ± 0.06[b]	n.s.	**	***	
Spleen			0.23 ± 0.02	0.23 ± 0.01	n.s.		†	
Thyroid			0.23 ± 0.03	0.24 ± 0.02	n.s.		n.s.	
Adrenal gland			0.10 ± 0.01	0.10 ± 0.01	n.s.		n.s.	age **
Thymus[1]			0.10 ± 0.02	0.10 ± 0.01	n.s.		n.s.	
Body dimension (mm)								
Crown-rump length[1]	154 ± 2[b]	151 ± 2[b]	168 ± 2[a]	169 ± 2[a]	n.s.	***	***	
Thoracic girth	114 ± 2[b]	118 ± 2[b]	128 ± 2[a]	129 ± 1[a]	n.s.	***	***	
Head circumference	121 ± 2[b]	122 ± 2[b]	128 ± 2[a]	130 ± 1[a]	n.s.	***	***	
Length of head			45.4 ± 0.8	46.0 ± 0.6	n.s.		***	
Mean length of forelimb cannon bones	18.3 ± 0.5	18.5 ± 0.5	18.0 ± 0.5	18.2 ± 0.4	n.s.	n.s.	*	

[1] Number of records in moderate group (Experiment 4.2) was 8 for this trait.

[a,b] Values within rows with different superscripts differ at the P<0.05 level.

n.s. = not significant, * P<0.05, ** P<0.01, *** P<0.001; missing value indicates that the variable was not fitted.

Table 8.3. Weight (g) of uterus, maternal and fetal membranes, total weight of all cotyledons and caruncles, mean weight of individual cotyledons and caruncles, number of cotyledons and number and utilisation (%) of caruncles at day 91 (Experiment 4.1) or day 90 (Experiment 4.2) of pregnancy for heifers fed for moderate or low liveweight gain from 21 days prior to insemination until slaughter. Rates of liveweight gain were 451 ± 16 versus 118 ± 32 g/day in Experiment 4.1 and 595 ± 30 versus 7 ± 23 g/day in Experiment 4.2, for moderate and low treatments, respectively. Values are LSM ± s.e.

	Experiment 4.1		Experiment 4.2		Significance		
	Moderate	Low	Moderate	Low	Treat-ment	Exp.	Other
n	8	8	9	15			
Weight of gravid uterus	2044 ± 104	2060 ± 104	2230 ± 98	2280 ± 76	n.s.	*	
Weight of maternal membranes	566 ± 26[b]	618 ± 26[ab]	643 ± 25[a]	648 ± 19[a]	n.s.	*	
Weight of fetal memb-ranes	213 ± 17[b]	262 ± 17[ab]	245 ± 16[ab]	273 ± 13[a]	0.074	n.s.	
Total weight of cotyledons	84 ± 6	94 ± 6	89 ± 5	95 ± 4	n.s.	n.s.	
Total weight of caruncles	81 ± 6	88 ± 6	93 ± 5	86 ± 4	n.s.	n.s.	
Mean weight of individual cotyledons	1.0 ± 0.1	1.2 ± 0.1	1.0 ± 0.1	1.1 ± 0.1	n.s.	n.s.	
Mean weight of individual caruncles	0.9 ± 0.1	1.1 ± 0.1	0.9 ± 0.1	0.9 ± 0.1	n.s.	n.s.	Int[1] *
Number of cotyledons	91 ± 8	90 ± 8	93 ± 8	93 ± 6	n.s.	n.s.	
Number of caruncles	103 ± 10	95 ± 9	103 ± 9	103 ± 7	n.s.	n.s.	Int[1] *
Caruncle utilisation	98 ± 6	97 ± 6	99 ± 6	99 ± 5	n.s.	n.s.	age *

[1] Int = interaction of sex of fetus with treatment-nested-within-experiment.
[a, b] Values within rows with different superscripts differ at the $P<0.05$ level.
n.s. = not significant, * $P<0.05$, ** $P<0.01$, *** $P<0.001$.

Discussion

The greater rate of liveweight gain observed in the moderate groups compared with the low groups was presumed to be induced by a greater feed intake by those groups. Sangsritavong (2002) reported that high feed intake increased liver blood flow in dairy cattle. Results from Hersom *et al.* (2004) indicated that increased liver weight relative to body weight was a reflection of increased metabolic rate in steers with a high compared with a low rate of liveweight gain. Therefore, it may be presumed that the increased weight of liver in the moderate heifers in the current experiments was indicative of a greater metabolic rate of these heifers compared with heifers in the low treatments.

Differences in maternal liveweight gain, liver weight, carcass weight and dressing out percentage indicate that the treatments successfully induced differences in the heifers in both experiments. Yet, similarities in fetal weight and size, weight of fetal organs and placental parameters between treatments indicated that fetal and placental growth remained largely unaffected by these maternal changes. The difference between treatments in fetal body weight observed in Experiment 4.1 was relatively small, and was not sufficient to indicate an effect of treatment across experiments. This is consistent with previous work that showed no effect on fetal weight or composition in response to variation in maternal energy intakes during pregnancy (Ferrell *et al.* 1976; Prior and Laster 1979), and no effect on birth weight of differing levels of maternal liveweight gain in the first trimester of pregnancy (Chapters 5 and 7).

The lack of differences in fetal-body-weight-adjusted fetal-size parameters indicated that fetuses from all treatments were developing at a similar rate relative to their increasing body weight. Similarities between treatments in fetal body dimensions are consistent with the finding that birth-weight-adjusted body dimensions of newborn calves were not affected by moderate or low maternal liveweight gain during the first trimester of pregnancy (Chapters 5 and 7).

Little is known about the effect of maternal nutrition on bovine fetal organ growth; however, studies in sheep have shown variable effects of maternal nutrition on the weight of fetal organs. Fetuses from underfed ewes have been reported to have similar body-weight-adjusted weight of liver, heart, brain and lungs (Quigley *et al.* 2005), kidneys and lungs (Vonnahme *et al.* 2003), and kidneys (Osgerby *et al.* 2002) to fetuses from well-fed ewes. Body-weight-adjusted weight of liver was greater in fetuses from nutrient-restricted compared with control ewes (Vonnahme *et al.* 2003), as was weight of fetal heart (Osgerby *et al.* 2002). The similarities in body-weight-adjusted organ weights among treatments that occurred in the present experiments are consistent with the general consensus from the above experiments in sheep.

There was no effect of treatment on the placental parameters considered in these experiments. This was consistent with the similarities amongst treatment groups for placental parameters at term of heifers fed for high or moderate liveweight gain for 10 days prior to insemination and for moderate or low liveweight gain for the first trimester of pregnancy (Chapter 6). This finding was in contrast to other studies: total cotyledon weight between day 90 and 255 of gestation was greater for heifers with low and medium energy intakes than for heifers with high energy intake (Prior and Laster 1979); and there were fewer, but larger, cotyledons at term from heifers fed for low compared with moderate liveweight gain in the first trimester of pregnancy but to reach the same live weight at parturition (Chapter 5). Cotyledon number was relatively fixed by day 90 of gestation (Prior and Laster 1979; Laven and Peters 2001), so it is likely that had these fetuses been carried to term, number of cotyledons would have remained similar among treatments.

Evidently, maternal nutrient restriction in the first trimester of pregnancy is unlikely to offer a means of restricting fetal growth and, therefore, of reducing the birth weight of the calf. The results presented here indicate that the converse may be the case, in that the fetus grows at a presumably genetically predetermined rate regardless of maternal liveweight change (at least within the conservative rates of liveweight gain considered here), and that the most effective way to minimise the incidence of dystocia in primiparous two-year-old heifers may be to ensure that the heifers also grow during this time, so that the risk of the feto-maternal disproportion is reduced. The absence of differences in the relative organ size and body dimensions of the fetuses indicates that such manipulation of maternal liveweight gain does not impose major changes to the relative growth of the fetus, although there may be some effect on organ function, which was not measured in these experiments.

Conclusions

A moderate compared with a low rate of maternal liveweight gain for 21 days prior to insemination and for the first trimester of pregnancy resulted in lighter fetuses per 100 kg maternal live weight at the end of the first trimester of pregnancy in Angus heifers bred at 15-months of age. Absolute weight and body dimensions of fetuses were similar among treatments. Relatively low liveweight gain of heifers in the first trimester of pregnancy was not a reliable method of manipulating fetal weight, and, therefore, did not offer a means of minimising dystocia in two-year-old beef heifers.

Implications

The results of this experiment confirm that maternal liveweight gain during early pregnancy did not consistently affect growth of the conceptus. There seems to be little potential to reduce dystocia using this approach. Therefore, although birth weight is the greatest single contributor to dystocia in primiparous heifers, there may be greater potential to manipulate secondary contributors to effectively manage dystocia. The first step toward achieving this would be to identify characteristics of the dam or calf that increased or decreased the probability of the heifer requiring assistance. This is the focus of Chapters 9 and 10.

CHAPTER 9

Duration of parturition and frequency of abdominal contractions in primiparous, two-year-old Angus heifers and the relevance of body dimensions of calves to dystocia

Publications arising from this chapter:

Hickson RE, Lopez-Villalobos N, Kenyon PR, Morris ST.
Duration of parturition and frequency of abdominal contractions in primiparous, 2-year-old Angus heifers and the relevance of body dimensions of calves to dystocia
Australian Journal of Experimental Agriculture 48, 935-9, 2008

Abstract

The predominant cause of dystocia in two-year-old heifers is feto-maternal disproportion, and consequently, birth weight of the calf explains much variation in dystocia. This experiment was carried out to identify other factors in addition to birth weight that contribute to the probability of assistance at parturition. Seventy-three primiparous, two-year-old, Angus heifers were observed continuously during the calving period, and records made of the time at which various events occurred during parturition. Frequency of abdominal contractions was lesser 30 minutes after onset of parturition than at 60-180 minutes after onset of parturition ($P<0.05$). The longest stage of parturition was the time from first abdominal contraction until appearance of amnion, whilst time from appearance of head until delivery of calf was the shortest stage. Frequency of abdominal contractions was negatively correlated with duration of parturition. Duration of parturition was less than 135 minutes for 75% of the non-assisted heifers. Body dimensions of calves did not explain any additional variation in assistance at parturition beyond that explained by birth weight and sex of calf and post-partum live weight of heifer. Calves that had an assisted birth took longer to attempt to stand, to stand and to suckle after birth than non-assisted calves. Within the non-assisted calves, there was no impact of duration of parturition on these behaviours of the newborn calf. In conclusion, body dimensions of the calf did not contribute to the probability of assistance at birth, but more frequent abdominal contractions contributed to a shorter duration of parturition. Behaviour of newborn calves was adversely affected by assistance at birth.

Introduction

Primiparous beef breeding heifers have been reported to experience a greater incidence of dystocia at parturition compared with mature cows (Wythes *et al.* 1976; Dargatz *et al.* 2004). Dystocia at parturition reduced viability of the calf and impaired the rebreeding performance of the heifer (Brinks *et al.* 1973; Rice 1994; Bennett 2006); however, calving heifers at two compared with three years of age increased the efficiency of the beef breeding cow herd (McMillan and McCall 1991; Chapter 2). Therefore, methods of reducing the incidence and severity of dystocia in primiparous, two-year-old, beef breeding heifers would enable farmers to achieve the efficiency gains associated with calving heifers at two years of age, whilst minimising dystocia and its consequences.

Birth weight of the calf is the primary contributor to dystocia in heifers (Philipsson 1976a; Lowman 1979; Rutter *et al.* 1983; Rice 1994; Arthur *et al.* 2000), yet there are reports of substantial variation in dystocia independent of variation in birth weight (Philipsson 1976a; Rutter *et al.* 1983). Experiments have shown no affect of body dimensions of the calf on dystocia once birth weight of the calf had been considered (Nugent and Notter 1991; Nugent *et al.* 1991). In spite of this, the beef cattle industry in New Zealand and Australia maintains some focus on body shape as a contributor to dystocia, with particular emphasis on the shape of the shoulders (Priest *et al.* 1998; Cumming 1999; Chapters 2 and 3). In addition to body dimensions of calves, the labour effort of the heifer has the potential to impact on dystocia, and prolonged parturition was postulated to be caused by inadequate labour effort of the dam in some cases (Dufty 1972a; Kroker and Cummins 1979).

The aims of this experiment were to: examine the duration of parturition and the frequency of abdominal contractions occurring at various stages of parturition in primiparous two-year-old Angus heifers; determine whether body dimensions of calves affected the probability of assistance at birth; and whether dystocia or duration of birth affected behaviour of the newborn calf.

Materials and methods

Animals and measurements

Seventy-three two-year-old Angus heifers (from the experiment reported in Chapter 6) that were diagnosed pregnant to a synchronised insemination with semen from five Angus bulls were grazed in two adjacent 2.6 and 4.3 ha paddocks from day 273 of gestation until parturition. From day 273 of gestation until parturition occurred, heifers were observed continuously by one or two persons at a time. The following observations were made on each heifer during parturition: time of onset of parturition, time of first abdominal contraction, time of first appearance of the amnion, time of first appearance of the forefeet of the fetus, time of first appearance of the nose of the fetus, time of first appearance of the head of the fetus (defined as the ears external to the vulva), and time at which the calf was born (defined as the time at which the calf's hips were external to the vulva). Onset of parturition was defined as obvious discomfort and restlessness, abdominal contractions, or the appearance of fetal membranes or discharge of fluid; whichever was first apparent. Beginning 30 minutes after onset of parturition and at 30 minute intervals thereafter until 120 minutes had passed, number of abdominal contractions was counted over a 5-minute period. If the calf was not born within 120 minutes, counting of contractions continued at 60-minute intervals until delivery. No attempt was made to quantify the strength or duration of the contractions. Following delivery of a live calf, the time was recorded at which the calf first attempted to stand, first stood successfully (on all four feet for 15 seconds or more), and the time at which the calf first suckled from any heifer.

If the calf was not born within four hours of the onset of parturition, or there had been two hours in which no progress had been made, the heifer was assisted to calve. Assistance was considered as a binomial trait (either assisted or non-assisted).

Within 24 hours of birth, all calves and their dams were weighed, and sex of calf was recorded. A 5 ml blood sample was taken from each of the live calves in a 10 ml vaccutainer via venipuncture of the jugular vein. Samples were centrifuged at 1500 rpm for 15 minutes and serum was frozen at -20°C. Samples were analysed by New Zealand Veterinary Pathology Limited, Palmerston North, in duplicate to determine creatine kinase and aspartate aminotransferase activity (Roche Hitachi 911 chemistry analyzer, Tokyo, Japan). Coefficient of variation for between-run precision was 1.0% for creatine kinase and 0.1% for aspartate aminotransferase.

The following body dimensions were measured on the live calves: body length, height at withers, depth of body (from the withers to the breast bone), circumference of head, width of shoulders (measured at the greater tubercle of the humerus), thoracic girth, width of hips, left and right forelimb cannon bone circumference and left and right forelimb cannon bone length (Nugent *et al.* 1991). The distance between the top of the left and right scapula was also recorded, as was the distance between the top of the left scapula and the top of the greater tubercle of the left humerus. Calves were standing upright while these measurements were made.

Statistical methods

Data were analysed in the Statistical Analysis System (SAS version 9.1, SAS Institute Inc., Cary, NC, USA, 2003). Duration of parturition variables were considered only for non-assisted heifers. Not all heifers had a complete set of observations made. Numbers for each trait are shown.

Total duration of parturition (time from onset of parturition until delivery of the calf) was analysed using the LIFETEST procedure for survival analysis. Frequency of abdominal contractions was analysed as a repeated measure using linear models in the MIXED procedure with time period as a fixed effect and allowing for the random effect of heifer to account for repeated measures. Pearson correlation coefficients were calculated using the CORR procedure.

For heifers with a complete set of observations, percentage of total duration of parturition for each stage was analysed using linear models in the MIXED procedure, and post-partum live weight of the heifer, birth weight of the calf and total duration of parturition were considered as covariates. The random effect of heifer was considered to allow for repeated measures. Birth weight and total duration of parturition had no significant effect on percentage of parturition time for any stage and were removed from the model.

The contribution of birthweight-adjusted body dimensions to the probability of assistance at birth was considered using the LOGISTIC procedure for logistic regression, with non-significant effects removed from the model. Body dimensions were adjusted for birth weight using the GLM procedure, and the residual body dimensions were fitted in the LOGISTIC model. Sire of calf was considered as a contributor to the probability of assistance at birth, but was excluded from the model because it had no effect. Behaviour of newborn calves was analysed with linear models in the GENMOD procedure using a logarithmic transformation and a Poisson distribution. Variables fitted in the GENMOD procedure are detailed in Table 9.2.

Pearson correlation coefficients were computed between total duration of parturition and creatine kinase and aspartate aminotransferase activity. Creatine kinase activity values were log-transformed to achieve a normal distribution. Aspartate aminotransferase activity and transformed creatine kinase activity were analysed using linear models in the MIXED procedure, with sex of calf and assistance at parturition considered as fixed effects and birth weight of calf as a covariable. Parameters without significant effect were removed from the model leaving only assistance at parturition in the model for aspartate aminotransferase activity and birth weight of calf and assistance at parturition in the model for creatine kinase activity. Minimum, maximum, median and upper and lower quartile values were calculated from the non-transformed values using the means procedure.

Heifers had been managed under different feeding regimes during pregnancy (Chapter 6), however, analysis revealed that the feeding treatments did not affect the parturition parameters considered and so treatment was excluded from the final models used.

Results

Twenty-five (34%) of the 73 heifers were assisted at calving. Malpresentation of the head or forelimbs contributed to four of the 25 assisted deliveries. Five assisted calves and one non-assisted calf were stillborn. The death of the non-assisted calf was not observed but was attributed to misadventure. Of the 48 non-assisted heifers, eight had no observations recorded, 27 had partial observations recorded and 13 had a complete set of observations. Total duration of calving was between 98 and 135 minutes for 50% of the non-assisted heifers for which this parameter was recorded (Figure 9.1). Frequency of contractions was lesser ($P<0.05$) at 30 minutes after the onset of parturition than at 60, 90, 120 and 180 minutes after the onset of parturition (Figure 9.2). Total duration of parturition was (or tended to be) negatively correlated with frequency of contractions at 30 ($r=-0.40$, $P=0.05$, $n=24$), 60 ($r=-0.40$, $P=0.05$, $n=24$), 90 ($r=-0.43$, $P<0.05$, $n=22$), 120 ($r=-0.47$, $P=0.09$, $n=14$) and 180 minutes ($r=-0.88$, $P<0.05$, $n=5$) after the onset of parturition.

The greatest proportion of parturition time was the stage from first abdominal contraction observed until appearance of the amnion (Figure 9.3). More than half of the total parturition time elapsed prior to appearance of the amnion, whereas time from appearance of nose until appearance of head, and time from appearance of head until delivery of calf made up only a small proportion of total parturition time. Duration of each stage of parturition decreased with increased post-partum live weight of the heifer.

Probability of assistance at birth was not affected by body dimensions of the calf, but increased with birth weight, decreased with post-partum maternal live weight and was greater for male than for female calves (Table 9.1).

Calves that experienced an assisted birth took longer to attempt to stand, to stand and to suckle than calves that experienced a non-assisted birth (Table 9.2). Heavier calves took longer to attempt to stand, to stand and to suckle than lighter calves, even with adjustment for assistance at parturition. Post-partum maternal live weight had both a quadratic and a linear relationship with behaviour of calves, and influenced the effect of birth weight on behaviour. Among calves that experienced a non-assisted birth, there was no affect of duration of parturition on time taken to attempt to stand, to stand or to suckle (data not shown).

Activities of creatine kinase and aspartate aminotransferase were greater (P<0.01) for assisted than non-assisted calves (Figure 9.4). Log-transformed creatine kinase activity but not aspartate aminotransferase activity was positively correlated with duration of birth for non-assisted calves (r=0.47, P<0.01).

Figure 9.1. Cumulative percentage of non-assisted, primiparous, Angus heifers (n=30) that calved at different times from onset parturition. Quartiles are indicated by circles.

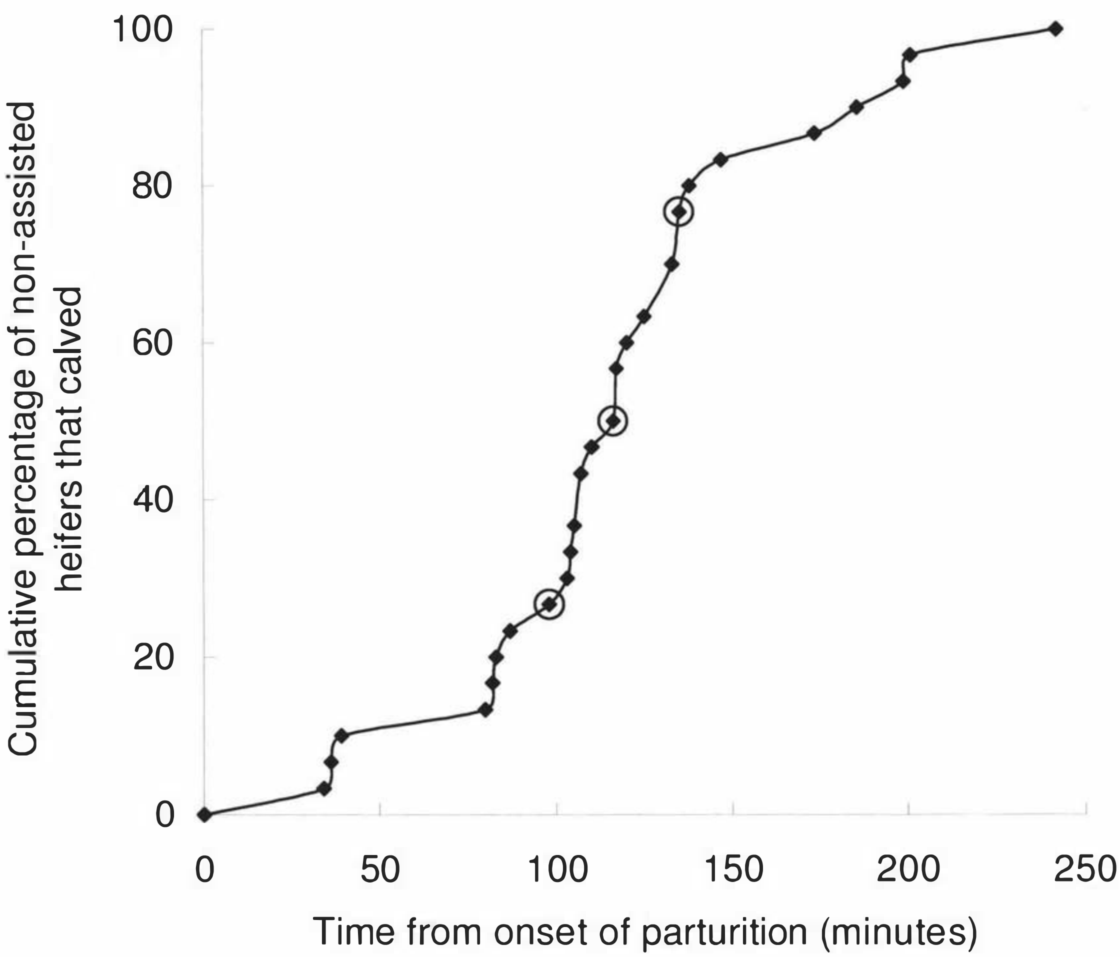


Figure 9.2. Number of abdominal contractions per minute at 30, 60, 90, 120, 180 and 240 minutes after the onset of parturition of non-assisted, primiparous, Angus heifers. Records taken within five minutes of delivery of the calf were excluded. A total of 87 observations were made on 33 heifers. Number of observations for each time point is shown. [a, b] Bars with different superscripts differ at the P<0.05 level.

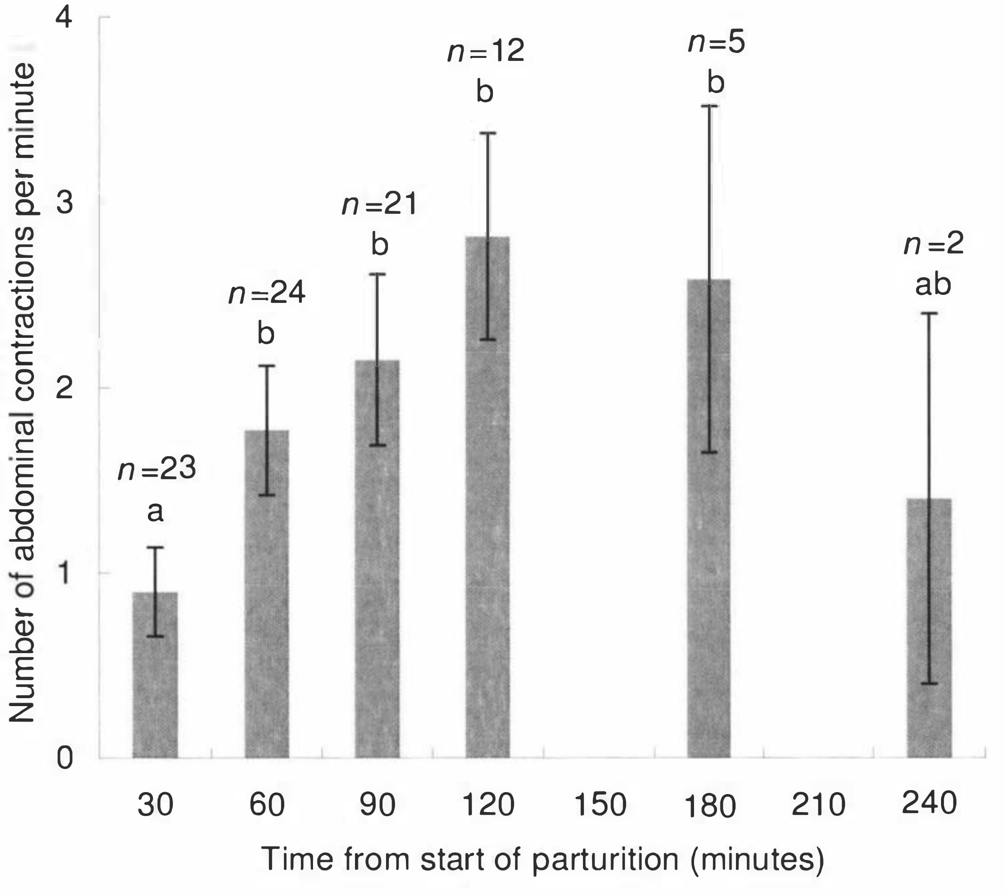


Figure 9.3. Duration of various stages of parturition expressed as a percentage of total duration of parturition ± s.e. for non-assisted, primiparous, Angus heifers (n=13). [a, b, c, d] Bars with different superscripts differ at the P<0.05 level. Stages of parturition were:

1. Onset of parturition until first contraction

2. First contraction until first appearance of amnion

3. First appearance of amnion until first appearance of forefeet

4. First appearance of forefeet until first appearance of nose

5. First appearance of nose until appearance of head

6. Appearance of head until birth of calf

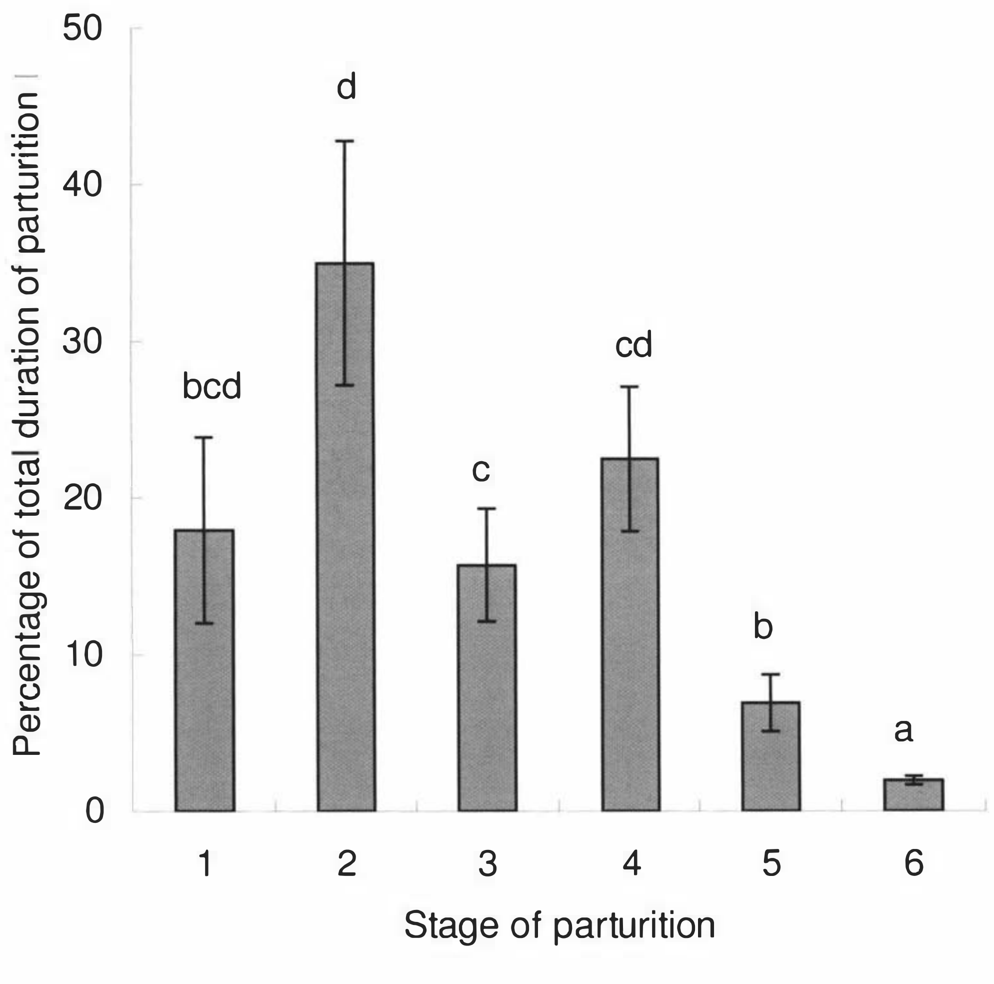


Table 9.1. Logistic regression coefficients and odds ratios for the probability of assistance at parturition for primiparous, two-year-old, Angus heifers (n=73), as affected by post-partum live weight of heifers and birth weight and sex of calves.

	Regression coefficient ± s.e.	Odds ratio (95% CI)	Significance
Post-partum live weight of heifer	-0.028 ± 0.009	0.97 (0.96–0.99)	**
Birth weight of calf	0.352 ± 0.101	1.42 (1.17–1.74)	***
Sex of calf			
Female	-0.714 ± 0.313	0.24 (0.07–0.82)	*
Male	0.0	1.0	

n.s. = not significant; * $P<0.05$; ** $P<0.01$; *** $P<0.001$

Figure 9.4. Box-and-whisker plots of serum activity of creatine kinase (CK) and aspartate aminotransferase (AST) within 24 hours of birth of assisted and non-assisted calves.

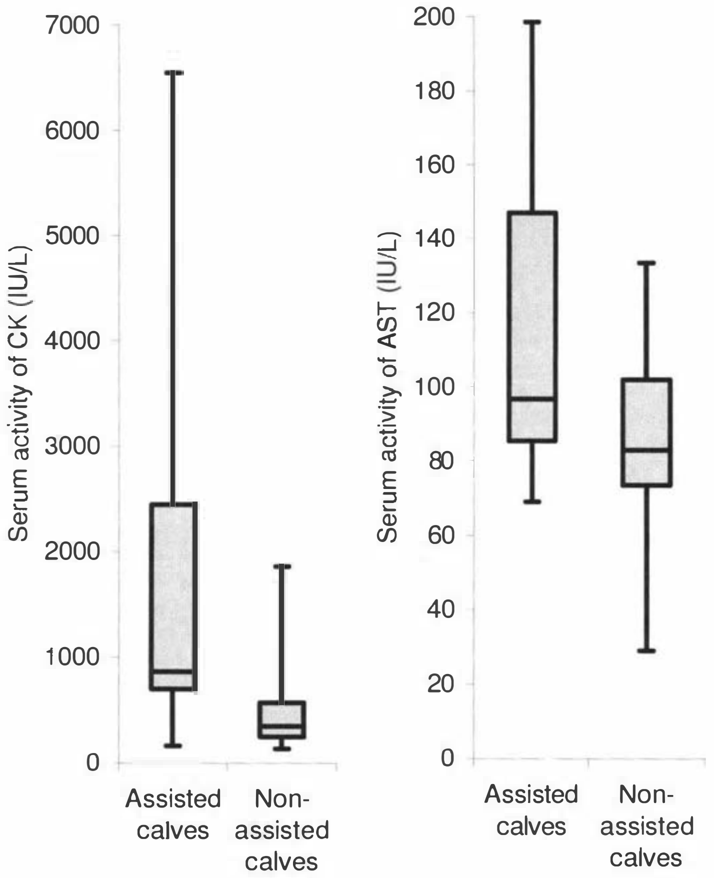


Table 9.2. Time elapsed after birth before calves that were born alive attempted to stand, successfully stood and suckled from a heifer for the first time as affected by assistance at birth, sex, sire and birth weight of calf and post-partum live weight of the heifer. Values are back-transformed LSM and regression coefficients (95% CI).

	Time (min) to		
	Attempt to stand	Stand	Suckle
n	50	51	38
Assisted at birth			
Yes	45.2[b] (40.4–50.7)	66.0[b] (59.9–72.8)	138.8[b] (125.9–153.0)
No	22.3[a] (20.6–24.1)	47.6[a] (45.1–50.2)	74.0[a] (70.5–77.6)
Sex of calf			
Female	32.0 (29.5–34.7)	59.9[b] (56.4–63.6)	133.6[b] (126.5–141.1)
Male	31.5 (28.5–34.9)	52.4[a] (48.3–57.0)	76.8[a] (70.5–83.8)
Sire of calf			
Bull 1	52.4[d] (45.1–60.9)	64.4[b] (56.3–73.7)	120.3[c] (105.6–137.0)
Bull 2	29.7[b] (27.0–32.6)	66.2[b] (61.8–71.0)	122.4[c] (114.3–131.2)
Bull 3	22.3[a] (18.6–26.8)	60.6[b] (53.6–68.5)	120.7[c] (108.3–134.5)
Bull 4	35.8[c] (32.4–39.5)	46.3[a] (42.4–50.6)	96.7[b] (89.6–104.3)
Bull 5	26.0[ab] (22.0–30.7)	46.2[a] (53.6–68.5)	62.2[a] (55.5–69.6)
Regression coefficients			
Linear birth weight	16.1*** (11.6–21.5)	1.8* (0.4–3.3)	10.2*** (8.2–12.4)
Linear post-partum live weight	4.3* (0.4–8.4)	n.s.	-5.9*** (-7.7–-4.0)
Quadratic birth weight	n.s.	n.s.	n.s.
Quadratic post-partum live weight	0.0* (0.0–6.0)	1.8** (0.6–3.0)	6.0*** (6.0–6.0)
Birth weight by post-partum live weight	-9.3*** (-11.8–-7.4)	-1.5** (-2.9–-0.5)	-5.9*** (-7.4–-4.9)

[a, b] Values within columns within sex, sire or assistance-at-birth classification with different superscripts differ at the $P<0.05$ level.

n.s. = not significant, * $P<0.05$, ** $P<0.01$, *** $P<0.001$

Discussion

Seventy-five percent of non-assisted heifers delivered their calf within 135 minutes from the onset of parturition. This indicated that the guidelines used in this experiment that recommended assisting heifers 240 minutes after the onset of parturition were sufficient to allow the majority of heifers that would have calved unassisted the opportunity to do so. Total duration of parturition in this experiment was shorter than the 148 ± 15 and 171 ± 14 minutes reported by Burnham *et al.* (2000) for two-year-old Hereford x Friesian heifers that delivered Charolais-sired calves. Those authors used displacement of the cervical seal as the onset of parturition, and the times included heifers that were assisted and the process of providing assistance may have contributed to the longer duration observed. Additionally, the use of Charolais sires in that experiment would have resulted in heifers delivering relatively larger calves, which could have further increased the duration of parturition. Dufty (1972a) reported a mean interval of 112 minutes between rupture of the amnion and normal delivery of the calf in two-year-old Hereford heifers penned for observation over calving, however, this mean included records of up to 391 minutes because assistance was not provided in that experiment. Similarly, Kroker and Cummins (1979) reported duration of parturition (from first appearance of amnion or fetal extremity till expulsion of the fetal hips) of 109.0 and 89.4 minutes for Hereford heifers fed for a high or maintenance plane of nutrition during the last trimester pregnancy, which was greater than in this study. In contrast, the 54.1 minutes duration of parturition (from first abdominal contraction until the calf was born) reported by Doornbos *et al.* (1984) was lesser than in the present study.

The negative correlations between frequency of contractions and total duration of parturition indicate that those heifers with more frequent abdominal contractions delivered their calves faster. This was in agreement with the suggestion by Kroker and Cummins (1979) that extended duration of parturition of heifers that had been underfed in late pregnancy was partially the result of a lesser labour effort by these heifers. The period in which there was least contractions generally coincided with the stage of parturition that constituted the greatest proportion of parturition time – time from first abdominal contraction until appearance of the amnion. These findings were in agreement with the report of Dufty (1972a), as was the rapid delivery of the calf once the head was external to the vulva.

As in previous experiments (Nugent and Notter 1991; Nugent *et al.* 1991; Chapter 7), birthweight-adjusted body dimensions of calves did not contribute to the probability of assistance at parturition once birth weight and sex of calf had been considered. These findings do not support the industry interest in body dimensions as a means of managing dystocia (Priest *et al.* 1998; Cumming 1999; Chapter 3). In agreement with previous experiments (Meijering 1984; Rice 1994), heavier calves had a greater probability of assistance at birth than lighter calves, whilst heifers of lesser post-partum live weight had a greater probability of assistance at parturition than heifers of greater post-partum live weight.

Time taken for calves to stand and to suckle in this experiment was intermediate between that of calves born to heifers fed on a high or maintenance plane of nutrition reported by Kroker and Cummins (1979). The increased time taken for assisted calves to attempt to stand, to stand, and to suckle from their dams may explain the lesser survival of assisted calves compared with non-assisted calves that is often observed (Rice 1994; Bennett 2006). There was an insufficient number of calves to draw conclusions regarding survival in the present experiment. Within calves experiencing a non-assisted birth, there was no advantage of a rapid birth in terms of time to attempt to stand, time to stand or time to suckle. The delay in time to stand and to suckle of heavier compared with lighter calves may be indicative of a more difficult birth, independent of the duration, especially considering that the effect of birth weight on behaviour was influenced by post-partum maternal live weight.

The elevated activity of creatine kinase and aspartate aminotransferase was indicative of muscle damage in the assisted calves (Sobiech and Kuleta 2002; Kozat 2007). This muscle damage may have contributed to the increased time take for the assisted calves to attempt to stand, to stand and to suckle. The positive correlation between log-transformed creatine kinase activity and duration of parturition may indicate a greater degree of muscle damage in those calves, although there was no impact on behaviour of the newborn calves in this case.

Conclusion

The findings of this experiment were in agreement with previous studies, as heavier calves were associated with an increased risk of assistance at parturition, and there was no effect of body dimensions of calves on the probability of assistance. A greater frequency of abdominal contractions was associated with a decreased duration of parturition, but within non-assisted calves, there was no effect of duration of parturition on time to stand or suckle. Behaviour of the newborn calf was unfavourably impacted upon by assistance at birth, as assisted calves took longer to stand and suckle than non-assisted calves.

Implications

These results indicate that altering body dimensions of the calves relative to birth weight would not reduce the incidence of dystocia in primiparous, two-year-old heifers; however, there was some evidence to support a role of the frequency of maternal contractions in dystocia, as measured by duration of parturition. Maternal contractions are hormonally regulated, so it may be worthwhile investigating maternal hormone concentrations in relation to dystocia and birth weight of the calf. Maternal plasma oestrone sulphate concentration prior to parturition is examined in Chapter 10.

CHAPTER 10

Maternal plasma oestrone sulphate concentration prior to parturition in relation to birth weight of the calf in primiparous, two-year-old Angus heifers

Publications arising from this chapter:

Hickson RE, Kenyon PR, Lopez-Villalobos N, Morris ST. Short communication: Maternal plasma oestrone sulphate concentration prior to parturition in relation to birth weight of the calf in primiparous, 2-year-old, Angus heifers. *Animal Reproduction Science* 114, 301-5, 2009

Abstract

Dystocia and assisted parturition in primiparous heifers are persistent problems in beef herds, and incidence increases with increasing birth weight of calves. Plasma samples taken from 33 primiparous, two-year-old, Angus heifers two days prior to parturition were analysed for oestrone sulphate concentration. Additional samples taken at 4, 6, 8 and ten days prior to parturition were analysed for 17 of these heifers. At parturition, birth weight of the calf, post-partum live weight of the heifer, assistance at calving (n=6) and status of the calf (stillborn (n=4) versus alive) were recorded. Maternal plasma oestrone sulphate concentration was stable from ten until four days prior to parturition and increased between four and two days prior to parturition for non-assisted heifers. Maternal plasma oestrone sulphate concentration did not affect the probability of assistance at parturition or stillbirth.

Introduction

The predominant cause of dystocia and assisted calving in primiparous two-year-old beef heifers is feto-maternal disproportion and the most important factor affecting the probability of dystocia is birth weight of the calf (Rice 1994; Chapters 5, 7 and 9). Birth weight of the calf is related to weight of cotyledons (Echternkamp 1993; Chapters 5 and 6), probably because cotyledons play a major role in the transfer of nutrients and metabolites between the maternal and fetal units (Shah *et al.* 2007). Furthermore, synthesis and conjugation of oestrogens occurs in the cotyledons; thus a positive correlation between the metabolic and steroidogenic capacity of the cotyledons and transfer of nutrients from the maternal bloodstream to the fetus would result in a positive correlation between maternal plasma oestrone sulphate concentration and birth weight (Shah *et al.* 2007).

Previous studies have indicated that maternal plasma oestrone sulphate concentration in the ten days prior to parturition was related to birth weight of the calf (Echternkamp 1993; Zhang *et al.* 1999a); however, there is conflicting evidence as to the stability of maternal plasma oestrone sulphate concentration during the ten days prior to parturition. Some authors reported that maternal plasma oestrone sulphate concentration did not change in the ten days prior to parturition (Echternkamp 1993; Zhang *et al.* 1999a), whereas others have reported variation during this period (Abdo *et al.* 1991; Kornmatitsuk *et al.* 2004). Zhang *et al.* (1999a; b) reported a positive correlation between neonatal viability and maternal plasma oestrone sulphate concentration, and also observed that the least viable calves had all experienced dystocia at birth, perhaps indicating the existence of a link between maternal plasma oestrone sulphate concentration and dystocia.

The aim of this experiment was to determine whether maternal plasma oestrone sulphate concentration prior to parturition was related to birth weight of the calf. A secondary objective was to determine whether maternal plasma oestrone sulphate concentration varied over the ten days prior to calving in primiparous, two-year-old, Angus heifers.

Materials and Methods

Animals and treatments

Thirty-three primiparous two-year-old Angus heifers were observed at least thrice daily (maximum time elapsed between observations was eight hours) during the parturition period to identify heifers in need of assistance to deliver their calf and to assess the status of the calf at birth (alive or stillborn). Assistance was provided at the discretion of the farm manager, using guidelines that recommended assisting heifers four hours after the onset of parturition. Each heifer had conceived to a single insemination with semen from one of five Angus bulls (BeefPac, LIC, Hamilton, New Zealand) at observed, synchronised oestrus (D0; n=23, or D1; n=10).

Two liveweight gain treatments were imposed from 21 days (one oestrous cycle) prior to insemination until D90 (end of first trimester of pregnancy). The treatments consisted of moderate (440 ± 32 g/day; n=17) and low liveweight gain (122 ± 35 g/day, n=16). There was no difference in pre-calving (D273) body condition score between treatments.

Measurements

From D264 to parturition (mean gestation length was 279 days, s.d. 3.5 days), a 5 ml blood sample was taken from each heifer daily in a 10 ml EDTA vaccutainer via venipuncture of the jugular vein. Samples were taken between 1330 and 1530 hours. Parturition occurred between two and 28 hours after the sample collected 'one day' prior to parturition. Oestrone sulphate concentration has been shown to increase rapidly in the 24 hours prior to parturition (Kindahl *et al.* 2002), thus there may have been substantial variation among heifers in the sample collected '1 day' prior to parturition, depending on the time at which they calved. This variation was avoided by using the sample collected two days (26–52 hours) prior to parturition.

Blood samples were immediately placed on ice and were centrifuged at 1500 rpm for 15 minutes within four hours of collection. Plasma samples were frozen at -20°C. Samples were analysed to determine oestrone sulphate concentration using double antibody radioimmunoassay (Diagnostic Systems Laboratories Australia, Gladesville, NSW). The assay sensitivity was 0.01 ng/ml and the inter- and intra-assay coefficients of variation were <10%. The sample collected two days prior to parturition was analysed for all 33 heifers and samples collected 4, 6, 8 and 10 days prior to parturition were analysed for 17 heifers.

Parturition was classified as assisted or non-assisted and heifers and calves were weighed and sex of calf was recorded within 24 hours of parturition. Calves that were born dead or died within 12 hours of parturition were classified as stillborn.

Statistical methods

Data were analysed using the Statistical Analysis System (SAS version 9.1, SAS Institute Inc., Cary, NC, USA, 2003). Liveweight gain treatment had no effect on any of the parameters considered and was removed from the models. Maternal plasma oestrone sulphate concentration over the ten days prior to calving was analysed using the MIXED procedure considering repeated measures for each heifer. The linear model considered the fixed effects of sex of calf and the covariables gestation length, birth weight of calf and day prior to parturition. Random effects were sire of calf, and heifer to account for repeated measures. Relevant interactions were considered in all models but were not significant so were excluded.

The probability of assistance at calving and the probability of stillbirth were analysed using the LOGISTIC procedure for logistic regression, with sex, sire and birth weight of calf, gestation length, post-partum live weight of the heifer and maternal plasma oestrone sulphate concentration two days prior to parturition considered as predictors. Non-significant effects ($P>0.1$; except maternal plasma oestrone sulphate concentration two days prior to parturition) were removed from the model. Significant effects are detailed in the results. Pearson correlation coefficients were calculated using the CORR procedure.

Results

Six (18%) of the 33 heifers were assisted at parturition and four calves (12%, including two assisted calves) were stillborn. All heifers delivered full-term, singleton calves, of which 10 were male and 23 were female. Of the 17 heifers that had maternal plasma oestrone sulphate concentration records for the ten days prior to parturition, three were assisted, and one non-assisted calf was stillborn.

Assisted calves were heavier than non-assisted calves (35.8 ± 1.5 vs. 31.1 ± 0.7 kg; $P<0.05$), but there was no difference in birth weight between stillborn calves and live calves (34.3 ± 2.0 vs. 31.7 ± 0.8 kg). There were no differences in post-partum live weight amongst these groups, but the ratio of birth weight of calf to post-partum live weight of the heifer was greater for assisted than for non-assisted heifers (data not shown). Maternal plasma oestrone sulphate concentration two days prior to parturition was positively correlated with birth weight of the calf ($r=0.41$; $P<0.05$; Figure 10.1) but not with post-partum liveweight of the heifer or the ratio of birth weight of the calf to post-partum live weight of the heifer. Birth weight of the calf was positively correlated with live weight of the heifer on D89 and D265 ($r=0.38$, $P<0.05$ and $r=0.50$, $P<0.01$, respectively).

Maternal plasma oestrone sulphate concentration was relatively stable during the ten days prior to parturition, although it was greater at two days prior to parturition than at four days prior to parturition for non-assisted heifers (Figure 10.2). Low numbers of assisted heifers and stillborn calves limited the power of the statistical analysis. Neither the probability of a heifer requiring assistance at parturition nor the probability of calf being stillborn were affected by maternal plasma oestrone sulphate concentration two days prior to parturition.

Figure 10.1. Birth weight of calves that were stillborn after a non-assisted birth (×; n=2), stillborn after an assisted birth (∗; n=2), born alive after an assisted birth (+; n=4) or born alive after a non-assisted birth (◇; n=25) in relation to maternal plasma oestrone sulphate concentration two days prior to parturition. The linear regression line represents the relationship between maternal plasma oestrone sulphate concentration two days prior to parturition and birth weight for all calves.

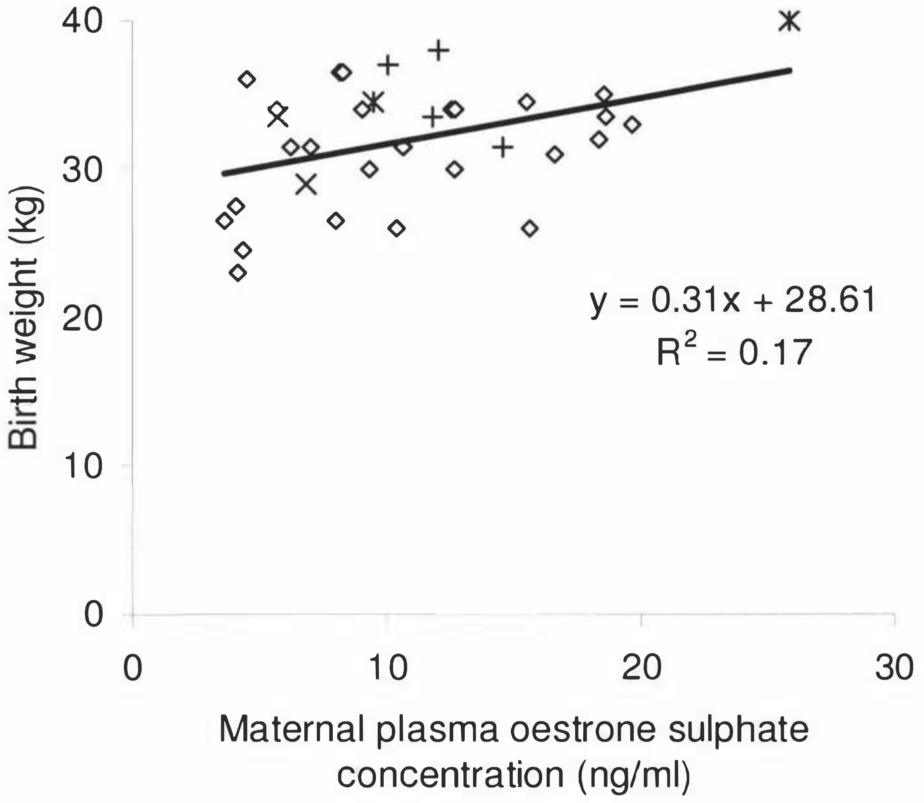
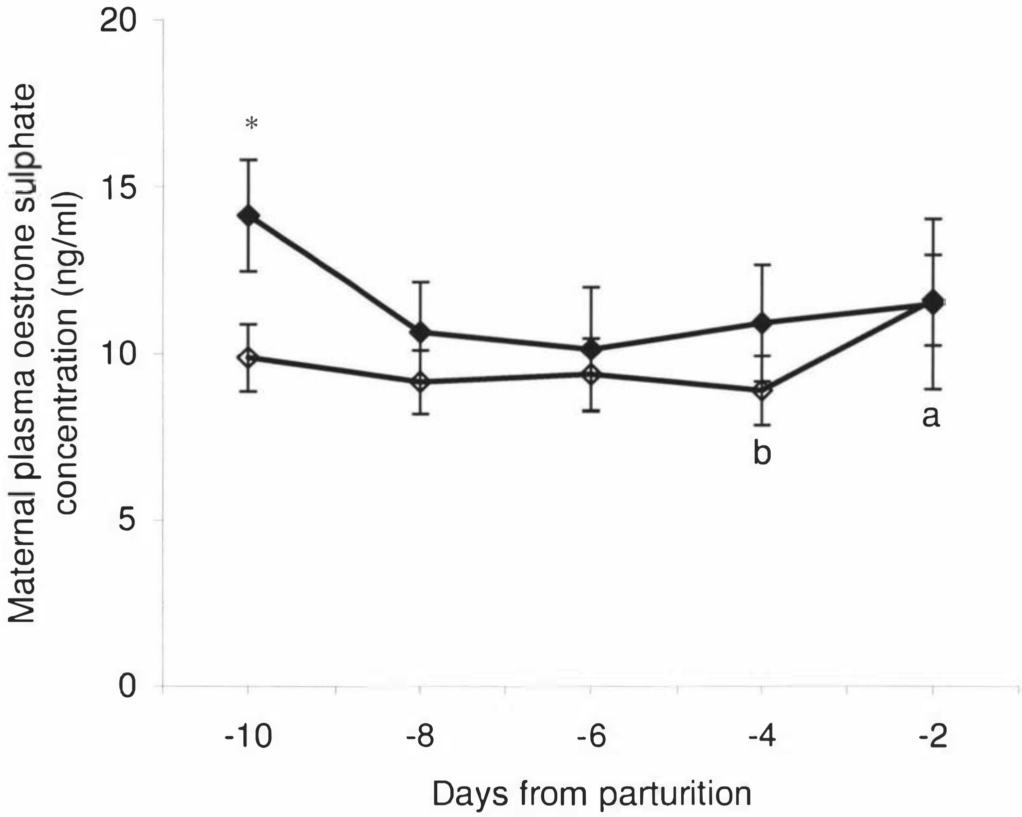


Figure 10.2. LSM and s.e. maternal plasma oestrone sulphate concentration of three assisted (◆) and 14 non-assisted (◇) primiparous two-year-old Angus heifers in the ten days prior to parturition. Data points within each group with different letters differ at the $P<0.05$ level. Time points marked with * differ between groups at the $P<0.05$ level.



Discussion

The results of this experiment were consistent with the findings of Echternkamp (1993) and Zhang *et al.* (1999a), in that maternal plasma oestrone sulphate concentration was stable during the ten days prior to parturition, with the exception that maternal plasma oestrone sulphate concentration was greater two days than four days prior to parturition for non-assisted heifers. Previous studies have shown a peak in maternal plasma oestrone sulphate concentration at or one day prior to parturition (Abdo *et al.* 1991; Kornmatitsuk *et al.* 2002; 2003; 2004). This is consistent with the increase between four and two days prior to parturition that was observed in the non-assisted heifers in the present experiment.

Previous studies have reported differences in maternal plasma oestrone sulphate concentration prior to parturition between assisted and non-assisted heifers. In two studies, assisted heifers had greater maternal plasma oestrone sulphate concentration than non-assisted heifers at the time of parturition (Kornmatitsuk *et al.* 2002; Sorge *et al.* 2008); however, in another study, assisted heifers exhibited less maternal plasma oestrone sulphate concentration for six days prior to parturition compared with non-assisted heifers, but concentrations were not different at ten days prior to parturition (Zhang *et al.* 1999b). In contrast, in the present experiment, assisted heifers had greater maternal plasma oestrone sulphate concentration than non-assisted heifers ten days prior to parturition, and did not show an increase two days prior to parturition whilst non-assisted heifers did. Zhang *et al.* (1999b) reported no difference in birth weight of calves between assisted and non-assisted heifers, whereas assisted calves in the present experiment were heavier than non-assisted calves. The inconsistency among these experiments may indicate that maternal plasma oestrone sulphate concentration is not a reliable indicator of the need for assistance. Alternatively, the few assisted heifers in this study or non-assisted heifers in the study by Zhang *et al.* (1999b) may not constitute a representative sample, or the reliability of maternal plasma oestrone sulphate concentration as an indicator of the need for assistance may be dependent on the cause of the dystocia.

The correlation between maternal plasma oestrone sulphate concentration two days prior to parturition and birth weight of the calf reported in the present experiment was less than previous reports: r=0.60 for maternal plasma oestrone sulphate concentration two days prior to parturition (Zhang *et al.* 1999a), and r=0.65 (Echternkamp 1993) and r=0.83 for mean maternal plasma oestrone sulphate concentration over the ten days before parturition (Shah *et al.* 2007). The low R^2 of birth weight regressed on maternal plasma oestrone sulphate concentration two days prior to parturition indicated that although there was a significant correlation between the parameters, the predictive value of maternal plasma oestrone sulphate concentration two days prior to parturition may be limited.

Oestrogens play an important role in initiating parturition in the cow, and are stimulants for myometrial activity, cervical dilation and synthesis of $PGF_{2\alpha}$; Zhang *et al.* (1999b) suggested that inadequate secretion of oestrone sulphate prior to delivery could impair these processes and result in assisted parturition. This hypothesis was not supported by the present experiment, in which not only was there no relationship between maternal plasma oestrone sulphate concentration and assisted parturition, but there was a positive correlation between birth weight of the calf and maternal plasma oestrone sulphate concentration. Incidence of assisted parturition is recognised to increase with increasing birth weight of the calf (Rice 1994; Chapters 5, 7 and 9), thus heifers in this experiment at potentially increased risk of assisted calving as indicated by less maternal plasma oestrone sulphate concentration also delivered lighter calves, which countered this risk.

Previous studies identified that heifers delivering stillborn calves had less maternal plasma oestrone sulphate concentration during the last three weeks of pregnancy (Echternkamp 1993; Kornmatitsuk *et al.* 2004). Other authors reported a positive correlation (r=0.65) between maternal plasma oestrone sulphate concentration two days prior to parturition and viability score of the newborn calf (Zhang *et al.* 1999a). These results contrast with the present experiment, in which there was no difference in birth weight or maternal plasma oestrone sulphate concentration between stillborn or live calves.

Conclusions

Maternal plasma oestrone sulphate concentration was constant from ten until four days prior to parturition, and increased between four and two days prior to parturition in non-assisted, primiparous, two-year-old, Angus heifers. Maternal plasma oestrone sulphate concentration two days prior to parturition was moderately correlated (r=0.41) with birth weight of the calf, but did not affect the probability of assistance.

CHAPTER 11

Concluding discussion

Introduction

The objective of the experimental work documented in this thesis was to determine whether maternal liveweight gain in the first trimester of pregnancy could be manipulated to effect a reduction in the birth weight of calves born to primiparous, two-year-old Angus heifers. Secondary objectives included: the identification of factors contributing to an increased risk of assistance at parturition in these heifers; examination of the consequences for productivity of variation in liveweight gain of heifers during the first trimester of pregnancy, and of assistance at parturition. Additionally, this thesis aimed to evaluate the impact of assisted calving in a simulated beef cattle herd as well as in industry, through a two-part survey of beef cattle farmers in New Zealand.

There is considerable potential to increase the profitability, productivity and efficiency of beef cattle herds in New Zealand through a reduction in dystocia and an accompanying decrease in assistance rate at parturition. A reduction in dystocia would achieve this increased profitability, productivity and efficiency in two ways; the first being an increase in profitability and performance of the beef herd on farms where heifers are currently calved at two years of age (Chapter 2), and the second being an increase in the number of herds in which heifers are calved at two years of age (Chapter 3). An additional benefit would be improved welfare of heifers calved at two years of age.

Dystocia in two-year-old heifers is affected primarily by birth weight of the calf (Philipsson 1976a; Johnson *et al.* 1988; Naazie *et al.* 1989; Rice 1994), through the influence of birth weight on the likelihood of feto-maternal disproportion, a condition in which the size of the calf is too great relative to the size of the heifer to allow a normal delivery (Meijering 1984; Rice 1994; Odde 1996). In light of the prevalence of feto-maternal disproportion as a contributor to dystocia (Holland *et al.* 1993), a reduction in birth weight of the calf relative to live weight of the heifer would be expected to result in a considerable reduction in the incidence of assisted calving. This expectation was the driver behind the experiments examining the effects of maternal liveweight gain in early pregnancy on birth weight of the calf, and on birth weight of the calf *relative* to maternal live weight.

Liveweight gain treatments

Birth weight of calves

The experiments presented in this thesis were largely consistent with respect to birth weight of calves: in all but one treatment (Chapter 6), there was no effect of liveweight gain of heifers in the first trimester of pregnancy on birth weight. Despite extensive work examining the effect of liveweight gain of heifers in late pregnancy on birth weight of the calf (Rice and Wiltbank 1972; Laster 1974; Drennan 1979; Kroker and Cummins 1979; Anderson *et al.* 1981; Axelsen *et al.* 1981; Bellows *et al.* 1982; Wiltbank and Remmenga 1982; Nicoll *et al.* 1984; Pleasants and Barton 1987, 1992; Spitzer *et al.* 1995), there have been few studies examining the effect of liveweight gain of heifers in early pregnancy on birth weight of the calf. Using retrospective analysis, Morris *et al.* (2004) identified a negative relationship between liveweight gain of mature cows one month after conception and birth weight of the calf.

From Chapter 5 it was evident that if total liveweight gain during pregnancy was similar between treatments, moderate compared with low liveweight gain of the heifer in the first trimester of pregnancy did not affect birth weight of the calf. Similarly, the experiment detailed in Chapter 7 revealed that low liveweight gain or liveweight loss of heifers for the first 42 or 90 days of pregnancy did not affect birth weight of calves compared with calves born to heifers fed for moderate liveweight gain during that time. This may have been partly due to the compensatory growth exhibited during the second and third trimesters of pregnancy by heifers in liveweight loss treatments, meaning that similar results to those reported in Chapter 5 were not unexpected. The heifers in these low treatments showed an effective ability to buffer nutrient supply to the fetus, as they produced calves of similar birth weight to those born to heifers in the moderate treatment, despite going through a period of substantial liveweight loss followed by a period of considerable compensatory growth on the same pasture allowance as heifers in the moderate treatment. The absolute nutrient requirements of the fetus in early gestation are very low (Ferrell *et al.* 1976; Robinson *et al.* 1999), so it is conceivable that the heifers could provide a buffer at this stage.

The experiment in Chapter 6 was somewhat different from those presented in Chapter 5 and Chapter 7 because the heifers in the groups that lost live weight during the first trimester of pregnancy grew at a slower rate for the second and third trimesters of pregnancy compared with those that had been fed for moderate liveweight gain during the first trimester of pregnancy. The difference in birth weight between calves born to the two heavy groups of heifers compared with calves born to the two light groups of heifers was consistent with previous research that has shown a reduction in birth weight from restricted feeding in late pregnancy (Laster 1974; Kroker and Cummins 1979; Bellows *et al.* 1982; Wiltbank and Remmenga 1982).

Calves born to heifers that had high liveweight gain pre-insemination and lost live weight in the first trimester of pregnancy delivered calves that were 3.2 kg lighter relative to live weight of their dams than calves born to heifers that had moderate liveweight gain prior to insemination followed by liveweight loss in the first trimester of pregnancy. The only stage at which these two groups of heifers differed in liveweight gain was during the 10 days prior to insemination, indicating that the effect of restriction of maternal liveweight gain during pregnancy may be mediated by liveweight gain prior to conception. The attempt to repeat this effect of the high to low switch at insemination on birth weight was unsuccessful, indicating that either this was a chance effect, or perhaps that in order for differences in fetal weight at term to result from restriction of maternal liveweight gain in early pregnancy, liveweight gain must be relatively low throughout pregnancy.

The similarity in fetal weights at the end of first trimester reported in Chapter 8 and the similar birth weights reported in Chapter 5 and 7, combined with the contrasting findings of Chapter 6 and Morris *et al.* (2004) indicate that manipulation of maternal liveweight gain in early pregnancy would not offer a reliable means of manipulating birth weight of the calf.

Live weight of calves

From a production perspective, the effect of nutritional treatments on birth weight of the calf can not be considered in isolation. It is important to also determine the consequences for other productive parameters, particularly growth of the calves to weaning and the subsequent growth and rebreeding of the dams. The three experiments were relatively consistent in these respects. Calves that were born at similar birth weight generally had similar live weight throughout the rearing period. Likewise, the two heavy groups of calves in Chapter 6 remained heavier than the two light groups of calves at least until 16 months of age. In contrast, previous studies examining the effects of liveweight gain of heifers in late pregnancy on live weight of calves have frequently reported no differences in live weight at weaning, even when differences were present at birth (Kroker and Cummins 1979; Pleasants and Barton 1992). These results imply that the potential benefit to dystocia of the low birth weight achieved was countered by a corresponding reduction in weaning weight of the calves, which would go some way towards negating any production increase resulting from reduced dystocia. Furthermore, one of the justifications for interest in nutritional methods of reducing birth weight of calves is to avoid the reduced mature live weight often associated with the use of bulls with EBV for low birth weight (Bennett and Gregory 2001a), an aim that was not met in this experiment.

Milk intake of calves

In all experiments, differences in milk intake were present at 40 days of age, but were no longer present by 60 days of age. In Chapters 5 and 6, differences in milk intake of the calves (and by inference, milk yield of the heifers) favoured heifers with greater liveweight gain in the second and third trimesters of pregnancy, whilst in Chapter 7, the least milk yield was recorded for heifers that had achieved the greatest liveweight gain during this time. Additionally, these heifers in Chapter 7 had less milk yield than heifers in the other two treatments on day 90 of lactation. A possible explanation for this may be that in that experiment, the heifers had achieved greater liveweight gain on the same rather than a greater pasture allowance, and may have compromised the development of their mammary tissue by partitioning nutrients to liveweight gain rather than mammary development. Wallace *et al.* (1996) reported that hoggets that grew rapidly during pregnancy produced less colostrum than their counterparts growing at a normal rate. Substantial development of the mammary gland occurs in the later stages of pregnancy (Ferrell *et al.* 1976; Swanson and Poffenbarger 1979), and reduced milk yield was reported in heifers with restricted liveweight gain in the last trimester of pregnancy in one of two experiments by Kroker and Cummins (1979). These results indicate that liveweight gain during late pregnancy was more important than liveweight gain during the first trimester of pregnancy for determining milk yield of the heifers, but the effects of liveweight gain in late pregnancy were not consistent across the experiments reported in this thesis or in the literature.

Subsequent performance of the heifers

The experiments reported in this thesis showed no lasting impact of liveweight gain during the first trimester of pregnancy on the live weight of heifers. In Chapters 5 and 7, there were no differences among treatments in the liveweight of heifers from immediately post partum until weaning. In Chapter 6, differences existed during the first lactation, but were completely eroded prior to second calving. Days to calving and inter-calving interval were not affected in Chapter 5 and 6, and pregnancy rate was similar among treatments in Chapter 7. This indicates that if 15-month-old heifers were fed for varying rates of liveweight gain during the first trimester of pregnancy, there was no lasting impact on live weight or rebreeding success. Varying feeding levels of heifers from weaning to first joining had no effect on the subsequent productivity of the heifers (Freetly and Cundiff 1998; Freetly *et al.* 2001), so it would seem likely that restricted liveweight gain during the first trimester of pregnancy would show a similar lack of effect.

Assistance at parturition

Sufficient numbers of heifers were assisted in the experiments reported in this thesis to allow comparisons to be made between performance during the rearing period of heifers and calves that were assisted at parturition/birth and those that experienced a normal delivery. Such comparisons were limited to some extent by the death of some assisted calves and culling of the corresponding heifers. Dead calves may have resulted from a biased sample of assisted animals, representing those that experienced more severe dystocia than calves that survived an assisted birth. Yet, this reflects the case on many beef cattle farms, as indicated in Chapter 4, so whilst these experiments may have considered a biased sample of assisted heifers, they are likely to have been representative of assisted heifers in industry.

In all experiments, calves born to assisted heifers were heavier at birth than non-assisted calves, in agreement with the importance of birth weight to dystocia (Philipsson 1976a; Lowman 1979; Rutter *et al.* 1983; Johnson *et al.* 1988; Naazie *et al.* 1989; Meadows *et al.* 1994; Rice 1994; Arthur *et al.* 2000). There were no differences in live weight at any other age between assisted and non-assisted calves. Assisted calves were slower than non-assisted calves to stand and suckle after birth, possibly indicative of impaired viability (Rice 1994). Milk intake of the calves was generally not affected by assistance at birth. These results indicate that the need for and provision of assistance at parturition did not negatively impact the subsequent performance of the surviving heifers and calves. This was in contrast with some reports in which assisted calves displayed depressed growth and reduced survival to weaning (Meijering 1984; Bennett 2006), although this difference may be explained by the prompt provision of assistance in the experiments presented in this thesis.

Factors affecting assistance at parturition

Birth weight of calves

In agreement with previous studies (Philipsson 1976a; Meijering 1984; Johnson *et al.* 1988; Rice 1994; Odde 1996), birth weight of the calf was a significant factor contributing to the probability of assistance at parturition. Interestingly, sex of the calf was a contributing factor after adjustment for birth weight in Chapters 5 and 9 but not in Chapter 7. This was similar to the contrasting reports from literature, where some studies have reported an effect of sex of the calf on dystocia independent of birth weight (Philipsson 1976a; Lowman 1979) whilst other studies have shown that the increased incidence of dystocia affecting male calves was attributable entirely to their increased birth weight (Laster *et al.* 1973; Price and Wiltbank 1978; Meijering 1984).

To assist with explaining this intermittent sex effect, the research documented in this thesis also examined body dimensions of calves and maternal plasma oestrone sulphate concentration prior to parturition as potential contributors to variation in assistance at birth that was not explained by variation in birth weight of the calf and live weight of the heifer.

Body dimensions of calves

Body dimensions of the calves did not contribute to the probability of assistance at birth after adjustment for birth weight, in agreement with reports by Nugent and Notter (1991) and Nugent *et al.* (1991). The sires used in Chapter 7 had divergent EBV for direct calving ease for similar genetic merit for birth weight, yet even calves from sires identified as above and below average EBV for direct calving ease showed no effect of body dimensions on the probability of assistance at birth. In spite of this, the survey of farmers revealed that 66% of respondents with two-year-old, primiparous heifers and 61% of respondents with three-year-old, primiparous heifers considered body shape when they selected service sires to join with maiden heifers. This selection pressure based on body shape could be better utilised focussed on EBV for birth weight or calving ease, or other traits relevant to production.

Maternal plasma oestrone sulphate concentration

Investigation of maternal plasma oestrone sulphate concentration two days prior to parturition as a contributor to assistance at parturition revealed that this parameter had a signification correlation with birth weight of the calf, but did not explain further variation in assistance at parturition. Assisted calves were heavier than non-assisted calves, in agreement with the preceding experiments, but there was no evidence for a role of maternal plasma oestrone sulphate concentration in assistance at parturition.

Genetic influences

Whilst not assessed in this research, the genes of the heifer and the calf (and, therefore, the genes of the sire) remain significant contributors to the probability of dystocia. The heritability of birth weight is sufficient (0.40–0.45) to enable selection of suitable service sires with breeding values for low birth weight to make a useful contribution to reduced birth weight of calves born to two-year-old heifers (Holland and Odde 1992). This was reflected in the high proportion of survey respondents calving heifers at two years of age who indicated that they considered breeding values for birth weight when selecting service sires.

The positive genetic correlation between live weight at birth and at later ages creates some difficulty in selecting for reduced birth weight without also accepting a reduction in the live weight of the calves later in life (Eriksson *et al.* 2004b). Recent work has demonstrated how concurrent selection using a selection index can be used to achieve improvements in postnatal growth alongside a reduction in birth weight and calving difficulty in primiparous two-year-old beef heifers. Bennett *et al.* (2008) reported that concurrent selection for decreased calving difficulty score in two-year-old heifers whilst increasing or maintaining yearling weight resulted in calves that were 3 kg lighter at birth, had 1.8 days shorter gestations and heifers in the select line had 20% less calving assistance than heifers in the control line over 7 years of selection. Weaning weight and yearling weight were similar between the selection lines. EBV of calves born in the final 2 years of the experiment were 1.06 units less for calving difficulty score (direct) and 3.5 kg less for birth weight in the select compared with control lines, whilst EBV for weaning and yearling weight were similar between the lines (Bennett 2008). These results illustrate that appropriate selection indices would enable a decrease in dystocia without also necessitating a reduction the liveweight of animals at weaning or one year of age.

The service sires used in the current experiments were in the best 30% for experiment 3 (Chapter 7), the best 20% for experiment 2 (Chapters 6 and 9) and the best 15% for experiment 1 (Chapter 5) of the population for EBV for birth weight of 2006-born Angus calves (New Zealand Angus Association 2008), yet incidences of assistance in the range 18–34% were observed. A probable factor contributing to the elevated assistance rate in this research was the intensive supervision of the heifers at parturition (Dufty 1981). Additionally, although the four-hour timeline for assistance was similar to the 3.2 hours reported for industry in Chapter 3, it is likely that continuous observation enabled onset of parturition to be identified earlier in heifers in this research than would occur in industry. Thus, conservative guidelines may have inflated the rate of assistance; however, the distribution of the duration of parturition for non-assisted heifers presented in Chapter 9 indicated that the guidelines were probably appropriate to differentiate between heifers that would have delivered a live calf without assistance and those that would not. Evidently, selection of a suitable service sire was not sufficient to ensure the heifers calved without assistance.

Considerations for the future

This thesis ruled out rate of maternal liveweight gain in the first trimester of pregnancy as a useful modifier of birth weight of calves born to two-year-old heifers. It would seem from this research, and from the considerable volume of literature relating to the last trimester of pregnancy, that the effects of nutritional manipulations on birth weight of calves, and more importantly, on dystocia in two-year-old heifers, are variable and inconsistent. The successful identification and implementation of a nutritional scheme to effectively manage dystocia in two-year-old heifers seems unlikely. A greater understanding of factors affecting nutrient partitioning in the pregnant heifer, particularly in a grazing system, would be useful for targeting future research into the potential for nutritional manipulation of birth weight.

Beyond the contribution of birth weight, there is much unexplained variation in dystocia. No additional factors (beyond birth weight and sex of the calf and live weight of the heifer) that contributed to the probability of assistance at parturition were identified in this thesis. The potential benefits to industry from reducing dystocia in primiparous, two-year-old heifers remain, however, and further work is justified to identify contributing factors. Further consideration of a range of maternal hormones as contributors to either birth weight of the calf or dystocia may also be justified.

There is known to be a genetic component to dystocia, and recent advances in genomic technologies may enable identification of genetic markers for dystocia, and potential interactions between genes, gene action and nutrition. Such investigations would require large numbers of heifers with known phenotypes for dystocia and known rates of liveweight gain or feeding level during pregnancy to be genotyped. The phenotypes could then be related to the genotypes to identify associations between particular single nucleotide polymorphisms and dystocia, along with potential interactions with nutrition. A previous experiment showed that adding zinc to the drinking water of heifers reduced the incidence of dystocia from 29% to 13%, implicating mineral nutrition in dystocia (Anonymous 1977). Additionally, hypocalcaemia has been implicated in increased dystocia in mature cows (Houe *et al.* 2001). Further examination of nutritional manipulation of dystocia could focus on these and possibly other minerals. Experimental examination of this should involve manipulation of the diet of heifers so that some heifers were deficient in the mineral of interest while others received adequate intake. Experiments that examined the effect of treatments directly on assistance rate, rather than on birth weight of the calf, would require many heifers per group to have sufficient power to examine the binomial trait. For example, to detect a difference between 10% and 20% assistance at parturition with 80% power and 5% level of significance (α), 157 heifers per group would be necessary, whilst 540 heifers per group would be required to detect a difference between assistance rates of 10% and 15%.

Implications of these findings

The implications of the finding that maternal liveweight gain in the first trimester had little impact on birth weight and subsequent live weight, milk intake and rebreeding performance of calves and heifers are two-fold. Firstly, this method has now been demonstrated as ineffective for averting assistance at parturition in primiparous, two-year-old, beef heifers so that farmers need no longer voluntarily impose such conditions on their heifers. Secondly, this research has shown that considerable variation in liveweight gain (and by inference, feed intake) of heifers in early pregnancy can be expected to have little effect on their subsequent performance, and such information is useful for making management decisions on farms when faced with the inevitable variation among years in the quantity and quality of pasture available to beef cattle herds in New Zealand.

Furthermore, this research demonstrated that at least if prompt assistance was provided to affected heifers, assistance at parturition/birth did not affect the performance of surviving, affected animals during the rearing period. When combined with the results of the simulation, that indicate a substantial improvement in profitability from calving heifers at two compared with three years of age if fewer than 89.4% of heifers were assisted at parturition, there seems little justification for beef cattle farmers in New Zealand not to calve heifers at two years of age provided incidence of dystocia remains below this threshold.

At the present time, the most effective method available to beef cattle farmers to minimise the incidence of dystocia in primiparous, two-year-old beef heifers is to select service sires of appropriate genetic merit for birth weight and direct calving ease (i.e. with low birth weight EBV and more positive direct calving ease EBV). Additionally, heifers should be well grown before joining. The consequences of dystocia in affected heifers could be alleviated by frequent observation of heifers at calving and prompt provision of assistance where necessary.

REFERENCES

Abdo GA, Njuguna OM, Fredriksson G, Madej A. Levels of oestrone sulphate during pregnancy in different breeds of cows and its possible association with retained foetal membranes. *Acta Veterinaria Scandinavica* 32, 183-8, 1991

Agricultural Business Research Institute. Angus group BREEDPLAN genetic trends table. Agricultural Business Research Institute, Armidale, Australia, 2006

Andersen KJ, Brinks JS, LeFever DG, Odde KG. A strategy for minimizing calving difficulty. *Veterinary Medicine* 88, 778-81, 1993

Anderson WJ, Pleasants AB, Barton RA. Effect of plane of nutrition on calf birth weight, calf growth rate, and subsequent performance of Angus heifers calving in spring. *New Zealand Journal of Agricultural Research* 24, 269-75, 1981

Anonymous. Handling calving difficulties. *Rural Research*, 21-4, 1977

Anonymous. Agricultural Production Statistics 2002. www.stats.govt.nz/tables/2002-ag-prod/beef-cattle-tables.htm. Statistics New Zealand, Wellington, New Zealand, 2003

Anonymous. Market Update weekly. www.marketupdate.co.nz. Napier, New Zealand, 2004

Anonymous. Market Update weekly. www.marketupdate.co.nz. Napier, New Zealand, 2005

Anonymous. Understanding estimated breeding values (EBVs). angusaustralia.com.au/BP_Understanding_EBVs.htm#CALVING_EASE. Angus Society of Australia, Armidale, Australia, 2007

Arthur PF, Archer JA, Melville GJ. Factors influencing dystocia and prediction of dystocia in Angus heifers selected for yearling growth rate. *Australian Journal of Agricultural Research* 51, 147-53, 2000

Axelsen A, Cunningham RB, Pullen KG. Effects of weight and pelvic area at mating on dystokia in beef heifers. *Australian Journal of Experimental Agriculture and Animal Husbandry* 21, 361-6, 1981

Azzam SM, Azzam AM, Nielsen MK, Kinder JE. Markov chains as a shortcut method to estimate age distributions in herds of beef cattle under different culling strategies. *Journal of Animal Science* 68, 5-14, 1990

Baker RL, Carter AH, Morris CA, Johnson DL. Evaluation of eleven cattle breeds for crossbred beef production: performance of progeny up to 13 months of age. *Animal Production* 50, 63-77, 1990

Baker RL, Carter AH, Muller JP. Performance of crossbred cows in the Ruakura beef breed evaluation trial. *Proceedings of the New Zealand Society of Animal Production* 41, 254-66, 1981

Bar-Anan R, Soller M, Bowman JC. Genetic and environmental factors affecting the incidence of difficult calving and perinatal calf mortality in Israeli-Friesian dairy herds. *Animal Production* 22, 299-310, 1976

Barker DJ, May PJ, Morris CA, Ridley PER. First calving performance of beef cattle. 1. Effects of moderate and slow growth between weaning and joining at 15 months of age. *Australian Journal of Experimental Agriculture* 25, 270-5, 1985

Barton RA. The yield and composition of milk of suckled beef cows and their relation to calf liveweight gains. In: Campbell AG (ed) *New Zealand beef production, processing and marketing.* Pp 130-40. New Zealand Institute of Agricultural Science (Inc). Petone, New Zealand, 1970

Basarab JA, Rutter LM, Day PA. The efficacy of predicting dystocia in yearling beef heifers: I. using ratios of pelvic area to birth weight or pelvic area to heifer weight. *Journal of Animal Science* 71, 1359-71, 1993a

Basarab JA, Rutter LM, Day PA. The efficacy of predicting dystocia in yearling beef heifers: II. using discriminant analysis. *Journal of Animal Science* 71, 1372-80, 1993b

Bell AW. Maternal nutrition, other factors affect birth weight. *Feedstuffs* 77, 10-2, 2005

Belling J Jr. Reproduction efficiency in the Hereford cow. *Journal of the American Veterinary Medical Association* 142, 494-501, 1963

Bellows RA, Gibson, RB, Anderson DC, Short, RE. Precalving body size and pelvic area relationships in Hereford heifers. *Journal of Animal Science* 33, 455-7, 1971a

Bellows RA, Short RE, Anderson DC, Knapp BW, Pahnish OF. Cause and effect relationships associated with calving difficulty and calf birth weight. *Journal of Animal Science* 33, 407-15, 1971b

Bellows RA, Short RE, Richardson GV. Effects of sire, age of dam and gestation feed level on dystocia and postpartum reproduction. *Journal of Animal Science* 55, 18-27, 1982

Bellows RA, Short RE, Staigmiller RB. Exercise and induced-parturition effects on dystocia and rebreeding in beef cattle. *Journal of Animal Science* 72, 1667-74, 1994

Bennett GL. Breeding value and phenotypic differences in seven cattle populations selected for calving ease. In: '8th World Congress on Genetics Applied to Livestock Production'. Belo Horizonte, Minas Gerais, Brasil 2006

Bennett GL. Experimental selection for calving ease and postnatal growth in seven cattle populations. I. Changes in estimated breeding values. *Journal of Animal Science* 86, 2093-102, 2008

Bennett GL, Gregory KE. Genetic (co)variances for calving difficulty score in composite and parental populations of beef cattle: I. Calving difficulty score, birth weight, weaning weight, and postweaning gain. *Journal of Animal Science* 79, 45-51, 2001a

Bennett GL, Gregory KE. Genetic (co)variances for calving difficulty score in composite and parental populations of beef cattle: II. Reproductive, skeletal, and carcass traits. *Journal of Animal Science* 79, 52-9, 2001b

Bennett GL, Thallman RM, Snelling WM, Kuehn LA. Experimental selection for calving ease and postnatal growth in seven cattle populations. II. Phenotypic differences. *Journal of Animal Science* 86, 2103-14, 2008

Berg RT. Breeding considerations for minimising difficult calving. In: Hoffman B, Mason IL, Schmidt J (eds). Calving problems and early viability of the calf: A seminar in the EEC programm of coordination of research on beef production held at Freisig, Federal Republic of Germany, May 4-6, 1977. Pp 133-40. Martinus Nijhoff Publishers, The Hague, 1979

Berger PJ, Cubas AC, Koehler KJ, Healey MH. Factors affecting dystocia and early calf mortality in Angus cows and heifers. *Journal of Animal Science* 70, 1775-86, 1992

Bernard C, Lalande G. The live weight of beef cows as influenced by age at first calving and wintering plane of nutrition. *Canadian Journal of Animal Science* 47, 23-30, 1967

Bernard CS, Fahmy MH, Lalande G. The influence of age at first calving and winter feeding management as yearlings on calf production from beef shorthorn cows. *Animal Production* 17, 53-8, 1973

Brinks JS, Olson JE, Carroll EJ. Calving difficulty and its association with subsequent productivity in Herefords. *Journal of Animal Science* 36, 11-7, 1973

Brown MA, Brown AH, Jackson WG, Miesner JR. Genotype x environment interactions in milk yield and quality in Angus, Brahman, and reciprocal-cross cows on different forage systems. *Journal of Animal Science* 79, 1643-9, 2001

Bryant JR, Holmes CW, Lopez-Villalobos N, McNaughton LR, Brookes IM, Verkerk GA, Pryce JE. Use of breeding values for live weight to calculate individual live weight targets for dairy heifers. *Proceedings of the New Zealand Society of Animal Production* 64, 118-21, 2004

Bureš D, Bartoň L, Zahrádková R, Teslík V, Fiedlerová M. Calving difficulty as related to body weights and measurements of cows and calves in a herd of Gascon breed. *Czech Journal of Animal Science* 53, 187-94, 2008

Burke JL, Morris ST, McCutcheon SN, Parker WJ. Compudose®: its effects on the growth, offspring performance, lactational performance, and carcass characteristics of Hereford × Friesian heifers at pasture. *Australian Journal of Agricultural Research* 49, 1167-72, 1998

Burnham DL, Morris ST, Holmes CW. Effect of pre-partum exercise on reproductive performance of first calving Hereford x Friesian heifers. In: 'Proceedings of the 9th Congress of the Asian-Australian Association of Animal Production Societies'. Sydney, Australia p 164, 2000

Carter AH, Cox EH. Observations on yearling mating of beef cattle. *Proceedings of the New Zealand Society of Animal Production* 33, 94-112, 1973

Carter F, Forde N, Duffy P, Wade M, Fair T, Crowe MA, Evans ACO, Kenny DA, Lonergan P. Effect of increasing progesterone concentration from day 3 of pregnancy on subsequent embryo survival and development in beef heifers. *Reproduction, Fertility, and Development* 20, 368-75, 2008

Charteris PL, Garrick DJ. Characterisation of beef cattle breeding industry structure. *Proceedings of the New Zealand Society of Animal Production* 56, 386-9, 1996

Colburn DJ, Deutscher GH, Nielsen MK, Adams DC. Effects of sire, dam traits, calf traits, and environment on dystocia and subsequent reproduction of two-year-old heifers. *Journal of Animal Science* 75, 1452-60, 1997

Cook TM, Russell RA. Introduction to management science, 5 edn. Prentice Hall, New Jersey, United States of America, 1993

Cooper K, Morris ST, McCutcheon SN. Effect of maternal nutrition during early and mid-gestation on fetal growth. *Proceedings of the New Zealand Society of Animal Production* 58, 175-7, 1998

Corah LR. Relationship of nutrition and dystocia. *Agri-Practice* 8, 26-8, 1987

Crews DH Jr. Age of dam and sex of calf adjustments and genetic parameters for gestation length in Charolais cattle. *Journal of Animal Science* 84, 25-31, 2006

Cumming B. Bull soundness - structural. www.agric.nsw.gov.au/reader/bullbuy/bullstructural.htm. New South Wales Department of Primary Industries, New South Wales, Australia, 1999

Cumming IA, Mole BJ, Obst J, Blockey MAD, Winfield CG, Goding JR. Increase in plasma progesterone caused by undernutrition during early pregnancy in the ewe. *Journal of Reproduction and Fertility* 24, 146-8, 1971

Cundiff LV, MacNeil MD, Gregory KE, Koch RM. Between- and within-breed genetic analysis of calving traits and survival to weaning in beef cattle. *Journal of Animal Science* 63, 27-33, 1986

Dargatz DA, Dewell GA, Mortimer RG. Calving and calving management of beef cows and heifers on cow-calf operations in the United States. *Theriogenology* 61, 997-1007, 2004

Doornbos DE, Bellows RA, Burfening PJ, Knapp BW. Effects of dam age, prepartum nutrition and duration of labor on productivity and postpartum reproduction in beef females. *Journal of Animal Science* 59, 1-10, 1984

Drennan MJ. Effect of plane of nutrition during late pregnancy on the incidence of calving problems in beef cows and heifers. In: Hoffman B, Mason IL, Schmidt J (eds). *Calving Problems and Early Viability of the Calf: A Seminar in the EEC Programme of Coordination of Research on Beef Production Held at Freisig, Federal Republic of Germany, May 4-6, 1977*. Pp 429-43. Martinus Nijhoff Publishers, The Hague, Netherlands, 1979

Dufty JH. Clinical studies on bovine parturition: maternal causes of dystocia and stillbirth in an experimental herd of Hereford cattle. *Australian Veterinary Journal* 48, 1-6, 1972a

Dufty JH. Dystocia and stillbirths in Hereford cattle. *Victorian Veterinary Proceedings* 1971-72, 41-4, 1972b

Dufty JH. Clinical studies of bovine parturition: foetal aspects. *Australian Veterinary Journal* 49, 177-82, 1973

Dufty JH. The influence of various degrees of confinement and supervision on the incidence of dystokia and stillbirths in Hereford heifers. *New Zealand Veterinary Journal* 29, 44-8, 1981

Echternkamp SE. Relationship between placental development and calf birth weight in beef cattle. *Animal Reproduction Science* 32, 1-13, 1993

Eriksson S, Nasholm A, Johansson K, Philipsson J. Genetic parameters for calving difficulty, stillbirth, and birth weight for Hereford and Charolais at first and later parities. *Journal of Animal Science* 82, 375-83, 2004a

Eriksson S, Nasholm A, Johansson K, Philipsson J. Genetic relationships between calving and carcass traits for Charolais and Hereford cattle in Sweden. *Journal of Animal Science* 82, 2269-76, 2004b

Everitt GC. Residual effects of prenatal nutrition on the postnatal performance of Merino sheep. *Proceedings of the New Zealand Society of Animal Production* 27, 52-68, 1967

Everitt GC. Calf growth and lifetime performance of beef cattle. *Proceedings of the New Zealand Society of Animal Production* 32, 20-5, 1972

Everitt GC, Evans ST. Beef production from the dairy herd: an analysis of mortalities. *New Zealand Veterinary Journal* 18, 132-9, 1970

Ferrell CL. Maternal and fetal influences on uterine and conceptus development in the cow: I. Growth of tissues in the gravid uterus. *Journal of Animal Science* 69, 1945-53, 1991a

Ferrell CL. Maternal and fetal influences on uterine and conceptus development in the cow: II. Blood flow and nutrient flux. *Journal of Animal Science* 69, 1954-65, 1991b

Ferrell CL, Garrett WN, Hinman N. Growth, development and composition of the udder and gravid uterus of beef heifers during pregnancy. *Journal of Animal Science* 42, 1477-89, 1976

Ferrell CL, Jenkins TG. Cow type and the nutritional environment: nutritional aspects. *Journal of Animal Science* 61, 725-41, 1985

Fiedlerová M, Řehák D, Vacek M, Volek J, Fiedler J, Šimeček P, Mašata O, Jílek F. Analysis of non-genetic factors affecting calving difficulty in the Czech Holstein population. *Czech Journal of Animal Science* 53, 284-91, 2008

Fielden ED, McFarlane D. Some aspects of the Gisborne beef cattle fertility survey. *Sheepfarming annual* 22, 29-39, 1959, non-peer-reviewed

Freetly HC, Cundiff LV. Reproductive performance, calf growth, and milk production of first-calf heifers sired by seven breeds and raised on different levels of nutrition. *Journal of Animal Science* 76, 1513-22, 1998

Freetly HC, Ferrell CL, Jenkins TG. Production performance of beef cows raised on three different nutritionally controlled heifer development programs. *Journal of Animal Science* 79, 819-26, 2001

Funston RN, Deutscher GH. Comparison of target breeding weight and breeding date for replacement beef heifers and effects on subsequent reproduction and calf performance. *Journal of Animal Science* 82, 3094-9, 2004

Gaines JD, Peschel D, Kauffman RG, Schaefer DM, Badtram G, Kumi-Diaka J, Clayton MK, Milliken G. Pelvic growth, calf birth weight and dystocia in Holstein x Hereford heifers. *Theriogenology* 40, 33-41, 1993

Garrett JE, Geisert RD, Zavy MT, Morgan GL. Evidence for maternal regulation of early conceptus growth and development in beef cattle. *Journal of Reproduction and Fertility* 84, 437-46, 1988

Garrick DJ, Pollak EJ, Quaas RL, Van Vleck LD. Variance heterogeneity in direct and maternal weight traits by sex and percent purebred for Simmental-sired calves. *Journal of Animal Science* 67, 2515-28, 1989

Hanly GJ, Mossman DH. Commercial beef production on hill country. *New Zealand Veterinary Journal* 25, 3-7, 1977

Hansen M, Lund MS, Pedersen J, Christensen LG. Gestation length in Danish Holsteins has weak genetic associations with stillbirth, calving difficulty, and calf size. *Livestock Production Science* 91, 23-33, 2004

Heasman L, Clarke L, Stephenson TJ, Symonds ME. The influence of maternal nutrient restriction in early to mid-pregnancy on placental and fetal development in sheep. *Proceedings of the Nutrition Society* 58, 283-8, 1999

Hersom MJ, Krehbiel CR, Horn GW. Effect of live weight gain of steers during winter grazing: II. Visceral organ mass, cellularity, and oxygen consumption. *Journal of Animal Science* 82, 184-97, 2004

Hight GK. The effects of undernutrition in late pregnancy on beef cattle production. *New Zealand Journal of Agricultural Research* 9, 479-90, 1966

Hodge PB, Beasley RC, Stokoe J. Effect of three levels of grazing nutrition upon calving and subsequent performance in Hereford heifers. *Proceedings of the Australian Society of Animal Production* 11, 245-8, 1976

Hodge PB, Stokoe J. Effect of varying periods of pre-calving nutrition upon the calving performance of Hereford heifers. *Proceedings of the Australian Society of Animal Production* 10, 59-64, 1974

Hodge PB, Wood SJ, Newman RD, Shepherd RK. Effect of calving supervision upon the calving performance of Hereford heifers. *Australian Veterinary Journal* 58, 97-100, 1982

Holland MD, Odde KG. Factors affecting calf birth weight: a review. *Theriogenology* 38, 769-98, 1992

Holland MD, Speer NC, LeFever DG, Taylor RE, Field TG, Odde KG. Factors contributing to dystocia due to fetal malpresentation in beef cattle. *Theriogenology* 39, 899-908, 1993

Houe H, Ostergaard S, Thilsing-Hansen T, Jorgensen RJ, Larsen T, Sorensen JT, Agger JF, Blom JY. Milk Fever and Subclinical Hypocalcaemia - An evaluation of parameters on incidence risk, diagnosis, risk factors and biological effects as input for a decision support system for disease control. *Acta Veterinaria Scandinavica* 42, 3-29, 2001

Johanson JM, Berger PJ. Birth weight as a predictor of calving ease and perinatal mortality in Holstein cattle. *Journal of Dairy Science* 86, 3745-55, 2003

Johnson DL, Baker RL, Morris CA, Carter AH, Hunter JC. Reciprocal crossbreeding of Angus and Hereford cattle 2. Steer growth and carcass traits. *New Zealand Journal of Agricultural Research* 29, 433-41, 1986

Johnson SK, Deutscher GH, Parkhurst A. Relationships of pelvic structure, body measurements, pelvic area and calving difficulty. *Journal of Animal Science* 66, 1081-8, 1988

Johnston DJ, Bunter KL. Days to calving in Angus cattle: genetic and environmental effects, and covariances with other traits. *Livestock Production Science* 45, 13-22, 1996

Joubert DM, Hammond J. A crossbreeding experiment with cattle, with special reference to the maternal effect in South Devon-Dexter crosses. *Journal of Agricultural Science, Cambridge* 51, 325-41, 1958

Kenyon PR, Morris ST, Perkins NR, West DM. Hogget mating in New Zealand - a survey. *Proceedings of the New Zealand Society of Animal Production* 64, 217-22, 2004

Khadem AA, Morris ST, Purchas RW, McCutcheon SN, Parker WJ. Growth, reproduction, and carcass and meat quality characteristics of once-bred Hereford x Friesian and Simmental x Friesian heifers managed for low or high liveweight gain during mid pregnancy. *New Zealand Journal of Agricultural Research* 39, 271-80, 1996

Kindahl H, Kornmatitsuk B, Konigsson K, Gustafsson H. Endocrine changes in late bovine pregnancy with special emphasis on fetal well-being. *Domestic Animal Endocrinology* 23, 321-8, 2002

King BD, Cohen RDH, McCormac S, Guenther CL. Maternal factors and the prediction of dystocia in beef heifers. *Canadian Journal of Animal Science* 73, 431-5, 1993

Kleemann DO, Walker SK, Hartwich KM, Fong L, Seamark RF, Robinson JS, Owens JA. Fetoplacental growth in sheep administered progesterone during the first three days of pregnancy. *Placenta* 22, 14-23, 2001

Koch RM, Cundiff LV, Gregory KE, van Vleck LD. Genetic response to selection for weaning weight or yearling weight or yearling weight and muscle score in Hereford cattle: Efficiency of gain, growth and carcass characteristics. *Journal of Animal Science* 82, 668-82, 2004

Kornmatitsuk B, Dahl E, Ropstad E, Beckers JF, Gustafsson HG, Kindahl H. Endocrine profiles, haematology and pregnancy outcomes of late pregnant Holstein dairy heifers sired by bulls giving a high or low incidence of stillbirth. *Acta Veterinaria Scandinavica* 45, 47-68, 2004

Kornmatitsuk B, Franzen G, Gustafsson H, Kindahl H. Endocrine measurements and calving performance of Swedish Red and White and Swedish Holstein dairy cattle with special respect to stillbirth. *Acta Veterinaria Scandinavica* 44, 21-33, 2003

Kornmatitsuk B, Veronesi MC, Madej A, Dahl E, Ropstad E, Beckers JF, Forsberg M, Gustafsson H, Kindahl H. Hormonal measurements in late pregnancy and parturition in dairy cows - possible tools to monitor foetal well being. *Animal Reproduction Science* 72, 153-64, 2002

Kozat S. Brief communication: Serum T_3 and T_4 concentrations in lambs with nutritional myodegeneration. *Journal of Veterinary Internal Medicine* 21, 1135-7, 2007

Kroker GA, Cummins LJ. The effect of nutritional restriction on Hereford heifers in late pregnancy. *Australian Veterinary Journal* 55, 467-76, 1979

Lamb RC, Barker BO, Anderson MJ, Walters JL. Effects of forced exercise on two-year-old Holstein heifers. *Journal of Dairy Science* 62, 1791-7, 1979

Larson RL, Tyler JW. Reducing calf losses in beef herds. *Veterinary Clinics Food Animal Practice* 21, 569-84, 2005

Laster DB. Factors affecting pelvic size and dystocia in beef cattle. *Journal of Animal Science* 38, 496-503, 1974

Laster DB, Glimp HA, Cundiff LV, Gregory KE. Factors affecting dystocia and the effects of dystocia on subsequent reproduction in beef cattle. *Journal of Animal Science* 36, 695-705, 1973

Laster DB, Gregory KE. Factors influencing peri- and early postnatal calf mortality. *Journal of Animal Science* 37, 1092-7, 1973

Laven RA. Life without oestradiol benzoate. Proceedings of the Society of Sheep and Beef Cattle Veterinarians of the New Zealand Veterinary Association 38, 173-7, 2008

Laven RA, Peters AR. Gross morphometry of the bovine placentome during gestation. *Reproduction in Domestic Animals* 36, 289-96, 2001

Lowman BG. Pre-calving management and feeding of the beef cow in relation to calving problems and viability of the calf. In: Hoffman B, Mason IL, Schmidt J (eds). *Calving Problems and Early Viability of the Calf: A Seminar in the EEC Programm of Coordination of Research on Beef Production Held at Freisig, Federal Republic of Germany, May 4-6, 1977*. Pp 392-407. Martinus Nijhoff Publishers, The Hague, Netherlands, 1979

Lucy MC, McDougall S, Nation NP. The use of hormonal treatments to improve the reproductive performance of lactating dairy cows in feedlot or pasture-based management systems. *Animal Reproduction Science* 82-83, 495-512, 2004

Mackenzie AJ, Edey TN. Short-term undernutrition and prenatal mortality in young and mature Merino ewes. *Journal of Agricultural Science* 84, 113-7, 1975

MacNeil MD. Genetic evaluation of the ratio of calf weaning weight to cow weight. *Journal of Animal Science* 83, 194-802, 2005

Makarechian M, Berg RT, Weingardt R. Factors influencing calving performance in range beef cattle. *Canadian Journal of Animal Science* 62, 345-52, 1982

McClintock SE, Beard KT, Goddard ME, Johnston DJ. Interactions between gestation length, calf size, dystocia and calf mortality. *Proceedings of the Association for the Advancement of Animal Breeding and Genetics* 16, 275-8, 2005

McFadden AM, Heuer C, Jackson R, West DM, Parkinson TJ. Reproductive performance of beef cow herds in New Zealand. *New Zealand Veterinary Journal* 53, 39-44, 2004

McMillan WH. Current and emerging reproductive technologies for beef breeding cows. *Proceedings of the New Zealand Society of Animal Production* 54, 345-50, 1994

McMillan WH, McCall DG. Are yearling heifer mating and more productive beef cow breeds a worthwhile use of winter feed? *Proceedings of the New Zealand Society of Animal Production* 51, 265-9, 1991

McMillan WH, Morris CA, McCall DG. Modelling herd efficiency in liveweight-selected and control Angus cattle. *Proceedings of the New Zealand Society of Animal Production* 52, 145-7, 1992

Meadows AW, Whittier WD, Eller I, Beal WE. Reducing dystocia in virgin beef heifers. *Veterinary Medicine* 89, 578-83, 1994

Meijering A. Dystocia and stillbirth in cattle: a review of causes, relations and implications. *Livestock Production Science* 11, 143-77, 1984

Meijering A, Postma A. Responses to sire selection for dystocia. *Livestock Production Science* 13, 251-66, 1985

Mellor DJ. Nutritional and placental determinants of foetal growth rate in sheep and consequences for the newborn lamb. *British Veterinary Journal* 139, 307-24, 1983

Montgomery GW. Perinatal mortality and deaths to weaning in beef cattle. Proceedings of the Society of Sheep and Beef Cattle Veterinarians of the New Zealand Veterinary Association 8, 31-6, 1978

Morris CA. Calving dates and subsequent intercalving intervals in New Zealand beef herds. *Animal Production* 39, 51-7, 1984

Morris CA, Archer JA. Application of new technologies in New Zealand for beef cattle and deer improvement. *New Zealand Journal of Agricultural Research* 50, 163-79, 2007

Morris CA, Baker RL, Bennett GL. Some genetic and non-genetic effects on the first oestrus and pregnancy rate of beef heifers. *Proceedings of the New Zealand Society of Animal Production* 46, 71-5, 1986a

Morris CA, Baker RL, Hickey SM, Johnson DL, Cullen NG, Wilson JA. Evidence of genotype by environment interaction for reproductive and maternal traits in beef cattle. *Animal Production* 56, 69-83, 1993

Morris CA, Bennett GL, Baker RL, Carter AH. Birth weight, dystocia and calf mortality in some New Zealand beef breeding herds. *Journal of Animal Science* 62, 327-43, 1986b

Morris CA, Smeaton DC, Pleasants AB. The effect of precalving and postcalving nutritional regimes on calf birth weight and preweaning growth. *Proceedings of the New Zealand Society of Animal Production* 64, 36-8, 2004

Morris ST. Avoiding dystocia in beef breeding cow herds. Proceedings of the Society of Sheep and Beef Cattle Veterinarians of the New Zealand Veterinary Association 24, 100-11, 1994

Morris ST, Morel PCH, Kenyon PR. The effect of individual liveweight and condition of beef cows on their reproductive performance and birth and weaning weights of calves. *New Zealand Veterinary Journal* 54, 96-100, 2006

Murphy MG, Enright WJ, Crowe MA, McConnell K, Spicer LJ, Boland MP, Roche JF. Effect of dietary intake on pattern of growth of dominant follicles during the oestrous cycle in beef heifers. *Journal of Reproduction and Fertility* 92: 333-8, 1991

Naazie A, Makarechian M, Berg RT. Factors influencing calving difficulty in beef heifers. *Journal of Animal Science* 67, 3243-9, 1989

Naazie A, Makarechian M, Berg RT. Genetic, phenotypic, and environmental parameter estimates of calving difficulty, weight, and measures of pelvic size in beef heifers. *Journal of Animal Science* 69, 4793-800, 1991

New Zealand Angus Association. Indexes. In: www.nzangus.com. 2005

New Zealand Angus Association. NZ Angus: Percentile bands for 2006-born calves. Retrieved from http://abri.une.edu.au/online/cgi-bin/i4.dll?1=3538202F&2=2323&3=56&5=2B3C2B3C3A. (Agricultural Business Research Institute) 2008

Newman S, Deland MP. Lifetime productivity of crossbred cows. 2. Age and weight at first oestrus, calf birth weight, assisted calvings, calving interval and reproduction rate. *Australian Journal of Experimental Agriculture* 31, 293-300, 1991

Nicol AM, Nicoll GB. Pastures for beef cattle. In: Nicol AM (ed) *Livestock Feeding on Pasture.* p 145. New Zealand Society of Animal Production, Christchurch, NZ, 1987

Nicoll GB, Smeaton DC, McGuire KR. Effect of herbage allowance on performance of pregnant beef heifers. *Proceedings of the New Zealand Society of Animal Production* 44, 173-6, 1984

Nix JM, Spitzer JC, Grimes LW, Burns GL, Plyler BB. A retrospective analysis of factors contributing to calf mortality and dystocia in beef cattle. *Theriogenology* 49, 1515-23, 1998

Nugent RA III, Notter DR. Body measurements of crossbred calves sired by Simmental bulls divergently selected for progeny first-calf calving ease in relation to birth weight. *Journal of Animal Science* 69, 2422-33, 1991

Nugent RA III, Notter DR, Beal WE. Body measurements of newborn calves and relationship of calf shape to sire breeding values for birth weight and calving ease. *Journal of Animal Science* 69, 2413-21, 1991

Nunez-Dominguez R, Cundiff LV, Dickerson GE, Gregory KE, Koch RM. Lifetime Production of Beef Heifers Calving 1st at 2 Vs 3 Years of Age. *Journal of Animal Science* 69, 3467-79, 1991

Odde KG. Reducing neonatal calf losses through selection, nutrition and management. *Agri-Practice* 17, 12-5, 1996

Osgerby JC, Wathes DC, Howard D, Gadd TS. The effect of maternal undernutrition on ovine fetal growth. *Journal of Endocrinology* 173, 131-41, 2002

Paputungan U, Makarechian M, Liu MF. Sources of variation in calving difficulty in beef heifers. *Asian-Australasian Journal of Animal Sciences* 7, 255-60, 1994

Parminter TG, Power MPB, Shaw DC. The effects on adoption of beef breeding cow technologies of selected farm business standards, farmer demographics, and farmer beliefs. *Proceedings of the New Zealand Society of Animal Production* 53, 121-5, 1993

Parr RA. Nutrition-progesterone interactions during early pregnancy in sheep. *Reproduction and Fertility Developments* 4, 297-300, 1992

Parr RA, Cumming IA, Clarke IJ. Effects of maternal nutrition and plasma progesterone concentrations on survival and growth of the sheep embryo in early gestation. *Journal of Agricultural Science, Cambridge* 98, 39-46, 1982

Parr RA, Williams AH, Campbell IP, Witcombe GF, Roberts AM. Low nutrition of ewes in early pregnancy and the residual effect on the offspring. *Journal of Agricultural Science, Cambridge* 106, 81-7, 1986

Patterson DJ, Bellows RA, Burfening PJ, Carr JB. Occurrence of neonatal and postnatal mortality in range beef cattle. I. Calf loss incidence from birth to weaning, backward and breech presentations and effects of calf loss on subsequent pregnancy rate of dams. *Theriogenology* 28, 557-71, 1987

Peachey BM, Morris ST. Effect of sward height during lactation on heifer and calf performance. *Proceedings of the New Zealand Grassland Association* 60, 225-8, 1998

Philipsson J. Calving performance and calf mortality. *Livestock Production Science* 3, 319-31, 1976a

Philipsson J. Studies on calving difficulty, stillbirth and associated factors in Swedish cattle breeds. III. Genetic parameters. *Acta Agriculturae Scandinavica* 26, 211-20, 1976b

Philipsson J. Studies on calving difficulty, stillbirth and associated factors in Swedish cattle breeds. IV. Relationships between calving performance, precalving body measurements and size of pelvic opening in Friesian heifers. *Acta Agriculturae Scandinavica* 26, 221-9, 1976c

Philipsson J, Foulley JL, Lederer J, Liboriussen T, Osinga A. Sire evaluation standards and breeding strategies for limiting dystocia and stillbirth. Report of an EEC/EAAP working group. *Livestock Production Science* 6, 111-27, 1979

Phocas F, Laloe D. Evaluation models and genetic parameters for calving difficulty in beef cattle. *Journal of Animal Science* 81, 933-8, 2003

Phocas F, Laloe D. Genetic parameters for birth and weaning traits in French specialized beef cattle breeds. *Livestock Production Science* 89, 121-8, 2004

Pinney DO, Stephens DF, Pope LS. Lifetime effects of winter supplemental feed level and age at first parturition on range beef cows. *Journal of Animal Science* 34, 1067-74, 1972

Pleasants AB, Barton RA. Effect of pre-calving liveweight gain of Angus heifers calving at two years of age on their subsequent milk yield and calf growth rate. *New Zealand Journal of Experimental Agriculture* 15, 151-3, 1987

Pleasants AB, Barton RA. Precalving nutrition of heavy two year old Angus heifers weighing 415 kg at calving. *Proceedings of the New Zealand Society of Animal Production* 52, 303-5, 1992

Price TD, Wiltbank JN. Dystocia in cattle. A review and implications. *Theriogenology* 9, 195-219, 1978

Priest R, Thomson RD, Packard PM, Garrick DJ, Morris ST. Bull selection: a beef council publication, Meat New Zealand, Fielding, New Zealand, 1998

Prior RL, Laster DB. Development of the bovine fetus. *Journal of Animal Science* 48, 1546-53, 1979

Probert AD. A study of aspects of beef cattle reproduction in the Manawatu district. Diploma of Veterinary Clinical Science thesis, Massey University, Palmerston North, New Zealand, 1989

Quigley SP, Kleemann DO, Kakar MA, Owens JA, Nattrass GS, Maddocks S, Walker SK. Myogenesis in sheep is altered by maternal feed intake during the peri-conception period. *Animal Reproduction Science* 87, 2005

Rabiee AR, Macmillan KL, Schwarzenberger F. The effect of level of feed intake on progesterone clearance rate by measuring faecal progesterone metabolites in grazing dairy cows. *Animal Reproduction Science* 67, 205-14, 2001

Rice LE. Dystocia-related risk factors. Veterinary Clinics of North America, Food Animal Practice 10, 53-68, 1994

Rice LE, Wiltbank JN. Factors affecting dystocia in beef heifers. *Journal of the American Veterinary Medical Association* 161, 1348-58, 1972

Ridler BJ, Rendel JM, Baker A. Driving innovation: application of Linear Programming to improving farm systems. *Proceedings of the New Zealand Grassland Association* 63, 295-8, 2001

Robbins CT, Robbins BL. Fetal and neonatal growth patterns and maternal reproductive effort in ungulates and subungulates. *The American Naturalist* 114, 101-16, 1979

Robinson JJ. The influence of maternal nutrition on ovine foetal growth. *Proceedings of the Nutrition Society* 36, 9-16, 1977

Robinson JJ, Ashworth CJ, Rooke JA, Mitchell LM, McEvoy TG. Nutrition and fertility in ruminant livestock. *Animal Feed Science and Technology* 126, 259-76, 2006

Robinson JJ, Sinclair KD, McEvoy TG. Nutritional effects on foetal growth. *Animal Science* 68, 315-31, 1999

Rutter LM, Ray DF, Roubicek CB. Factors affecting and prediction of dystocia in Charolais heifers. *Journal of Animal Science* 57, 1077-83, 1983

Sangsritavong S, Combs DK, Sartori R, Armentano LE, Wiltbank MC. High feed intake increases liver blood flow and metabolism of progesterone and estradiol-17 beta in dairy cattle. *Journal of Dairy Science* 85, 2831-42, 2002

Sawyer GJ, Barker DJ, Morris RJ. Performance of young breeding cattle in commercial herds in the south-west of Western Australia. 3. Calf growth, dystocia, and their relationship with production and fertility measurements in first-calf heifers. *Australian Journal of Experimental Agriculture* 31, 455-65, 1991

Schlote W, Hassig H. Investigations on the relationships of body measurements and weight of heifer and calf to calving difficulties in German Simmental (Fleckvieh) cattle. Preliminary results of the EEC Project No. 320 of the beef production programme. In: Hoffman B, Mason IL, Schmidt J (eds). *Calving Problems and Early Viability of the Calf: A Seminar in the EEC Programm of Coordination of Research on Beef Production Held at Freisig, Federal Republic of Germany, May 4-6, 1977*. Pp 220-9. Martinus Nijhoff Publishers, The Hague, Netherlands, 1979

Sejrsen K, Purup S, Vestergaard M, Foldager J. High body weight gain and reduced bovine mammary growth: physiological basis and implications for milk yield potential. *Domestic Animal Endocrinology* 19, 93-104, 2000

Shah KD, Nakao T, Kubota H, Maeda T. Relationship of prepartum plasma concentrations of estrone sulfate and estradiol-17β with the weight of the calf and placental parameters in Holstein-Friesian cows. *Animal Science Journal* 78, 489-94, 2007

Singh J, Singh B, Wadhwa M, Bakshi MPS. Effect of level of feeding on the performance of crossbred cows during pre- and post-partum periods. *Asian-Australasian Journal of Animal Sciences* 16, 1749-54, 2003

Sloss V. A clinical study of dystocia in cattle. 1. Treatment. *Australian Veterinary Journal* 50, 290-3, 1974

Smeaton DC. Beef cattle: yearling mating: points to consider on hill country. *Aglink* 83, 107-9, 1983

Smith GM, Laster DB, Gregory KE. Characterization of biological types of cattle. 1. Dystocia and preweaning growth. *Journal of Animal Science* 43, 27-36, 1976

Sobiech P, Kuleta Z. Usefulness of some biochemical indicators in detection of early stages of nutritional muscular dystrophy in lambs. *Small Ruminant Research* 45, 209-15, 2002

Sorensen AM Jr. Animal reproduction: principles and practices, McGraw-Hill Book Company, New York, 1979

Sorge US, Kelton DF, Staufenbiel R. Short communication: Prepartal concentration of estradiol-17β in heifers with stillborn calves. *Journal of Dairy Science* 91, 1433-7, 2008

Spitzer JC, Morrison DG, Wettemann RP, Faulkner LC. Reproductive responses and calf birth and weaning weights as affected by body condition at parturition and postpartum weight gain in primiparous beef cows. *Journal of Animal Science* 73, 1251-7, 1995

Swanson EW, Poffenbarger JI. Mammary gland development of dairy heifers during their first gestation. *Journal of Dairy Science* 62, 702-14, 1979

Symonds ME, Heasman L, Clarke L, Firth K, Stephenson T. Maternal nutrition and disproportionate placental-to-fetal growth. *Biochemical Society Transactions* 26, 91-6, 1998

Thatcher WW, Wilcox CJ, Collier RJ, Eley DS, Head HH. Bovine conceptus - maternal interactions during the pre- and postpartum periods. *Journal of Dairy Science* 63, 1530-40, 1980

Thomas CW, Campbell AC, Bywater AC. A benchmarking survey of commercial beef cow production: Canterbury 2004-05. *Proceedings of the Society of Sheep and Beef Cattle Veterinarians of the New Zealand Veterinary Association* 37, 69-79, 2007

Van Donkersgoed J. A critical analysis of pelvic measurements and dystocia in beef heifers. *Compendium on Continuing Education for the Practicing Veterinarian* 14, 405-9, 1992

Van Donkersgoed J, Ribble CS, Townsend HGG, Janzen ED. The usefulness of pelvic area measurements as an on-farm test for predicting calving difficulty in beef heifers. *Canadian Veterinary Journal* 31, 190-3, 1990

Vonnahme KA, Hess BW, Hansen TR, McCormick RJ, Rule DC, Moss GE, Murdoch WJ, Nijland MJ, Skinner DC, Nathanielsz PW, Ford SP. Maternal undernutrition from early- to mid-gestation leads to growth retardation, cardiac ventricular hypertrophy, and increased liver weight in the fetal sheep. *Biology of Reproduction* 69, 2003

Wallace JM, Aitken RP, Cheyne MA. Nutrient partitioning and fetal growth in rapidly growing adolescent ewes. *Journal of Reproduction and Fertility* 107, 183-90, 1996

Wallace JM, Bourke DA, Aitken RP, Cruickshank MA. Switching maternal dietary intake at the end of the first trimester has profound effects on placental development and fetal growth in adolescent ewes carrying singleton fetuses. *Biology of Reproduction* 61, 101-10, 1999

Wallace JM, Regnault TRH, Limesand SW, Hay WW, Anthony RV. Investigating the causes of low birth weight in contrasting ovine paradigms. *Journal of Physiology London* 565, 19-26, 2005

Webby RW, Bywater AC. Principles of feed planning and management. In: Rattray PV, Brookes IM, Nicol AM (eds). *Pasture and supplements for grazing animals.* Pp 189-220. New Zealand Society of Animal Production (Inc.), Hamilton, New Zealand, 2007

Whittier WD, Eller AL, Beal WE. Management changes to reduce dystocia in virgin beef heifers. *Agri-Practice* 15, 26-32, 1994

Wiltbank JN, Remmenga EE. Calving difficulty and calf survival in beef cows fed two energy levels. *Theriogenology* 17, 587-602, 1982

Wolverton DJ, Perkins NR, Hoffsis GF. Veterinary application of pelvimetry in beef cattle. *Compendium on Continuing Education for the Practicing Veterinarian* 13, 1315-21, 1991

Wu GY, Bazer FW, Cudd TA, Meininger CJ, Spencer TE. Maternal nutrition and fetal development. *Journal of Nutrition* 134, 2169-72, 2004

Wythes JR, Strachan RT, Durand MRE. A survey of dystocia in beef cattle in southern Queensland. *Australian Veterinary Journal* 52, 570-4, 1976

Young JS. Infertility in range cattle. *New Zealand Veterinary Journal* 13, 1-10, 1965

Zhang WC, Nakao T, Moriyoshi M, Nakada K, Ohtaki T, Ribadu AY, Tanaka Y. The relationship between plasma oestrone sulphate concentrations in pregnant dairy cattle and calf birth weight, calf viability, placental weight and placental expulsion. *Animal Reproduction Science* 54, 169-78, 1999a

Zhang WC, Nakao T, Moriyoshi M, Nakada K, Ribadu AY, Ohtaki T, Tanaka Y. Relationship of maternal plasma progesterone and estrone sulfate to dystocia in Holstein-Friesian heifers and cows. *Journal of Veterinary Medical Science* 61, 909-13, 1999b

APPENDIX

Questionnaires for the surveys reported in Chapters 3 & 4

Heifer Survey Heifer Survey Heifer Survey

Please complete one survey for each herd that you have different management strategies for. (eg. if you have a commercial herd and a stud herd that are managed differently, please complete a separate survey form for each herd. If you require additional survey forms, please email heifer.survey@massey.ac.nz. Additionally, please ensure that only one survey is completed per beef herd. Thank you.

. What was the age of your first-calving heifers in 2006?
- ☐ 2 years (mated at approx. 15 months) - Please complete blue & red sections
- ☐ 3 years (mated at approx. 27 months) - Please complete green & red sections
- ☐ Some 2 years and some 3 years - Please complete blue, green & red sections
- ☐ Other (what age?____________) - Please complete red section

Blue section

2. What reasons led you to breed heifers at 15-months?
please rate the importance of these reasons by circling a number on a scale of -5, 1=not important, 5=very important)

	Not important...very important
ncreased profit	1 2 3 4 5
More calves per cow over her lifetime	1 2 3 4 5
Fewer mobs over winter	1 2 3 4 5
Earlier selection of replacements	1 2 3 4 5
The unproductive period of the heifers is reduced	1 2 3 4 5
Reduces mature size of heifers so less feed required for maintenance over life	1 2 3 4 5
ncreased rate of genetic gain	1 2 3 4 5
Eliminates the need to keep empty R2 heifers away from bulls	1 2 3 4 5
Allows you to operate a once-bred heifer system	1 2 3 4 5

How do you select heifers to be mated at 15 months?
- ☐ Mate only those heifers that have reached a specific weight (minimum weight:__________)
- ☐ Select heifers based on daughters' calving ease EBV
- ☐ Buy in-calf R2 heifers
- ☐ Mate all heifers

What criteria do you use for selecting bulls to mate 15-month heifers? (tick all that apply)
- ☐ Cost of bull
- ☐ Breed (specify:____________________)
- ☐ EBV birth weight: ☐ high ☐ low ☐ moderate
- ☐ EBV 200/400/600 day weight: ☐ high ☐ low
- ☐ EBV direct calving ease: ☐ high ☐ low
- ☐ EBV gestation length: prefer ☐ high ☐ low
- ☐ Select based on a selection index (specify: ________________)
- ☐ Age of bull: ☐ yearling ☐ 2-yr-old ☐ mature bull
- ☐ Weight of bull at joining
- ☐ Shape of bull: ☐ smooth & narrow shoulders ☐ long body ☐ narrow & angular hips and rump
- ☐ A bull previously used over heifers

How many 2-year-old heifers calved in 2006? __________

How many 2-year-old heifers did you assist at calving in 2006? ____________

How much of a problem do you consider calving difficulty to be in your 2-year-old heifers? (circle a number on scale 1-5; 1 = not a problem, 5 = major problem)
Not a problem ... 1 2 3 4 5 ... A major problem

What is the frequency of supervision of your 2-year-old heifers during calving?
- ☐ More than twice daily
- ☐ Twice daily
- ☐ Once daily
- ☐ Less than once daily

How did you manage calving difficulty in your 2-year-old heifers that calved in 2006 and what have you tried in the past? (tick all that apply)

	2006	Tried in the past
No particular strategies	☐	☐
Selected an appropriate bull	☐	☐
Low feeding in late pregnancy	☐	☐
Low feeding in early pregnancy/joining	☐	☐
Wintered on hill paddocks	☐	☐
Only bred from heifers above a certain weight	☐	☐
Generated replacement heifers from sires with a high daughters' calving ease EBV	☐	☐
Fed hay/other supplements in evening to minimise the number of heifers calving at night	☐	☐
Other (specify____________________________)		

0. How many 15-month-old heifers were joined with bulls in the 2006/07 breeding season? ______________

1. How many bulls were joined with those heifers? ______________

2. How long was/is that joining period in 2006/07? ______________

Red Section

4. In what region is your farm located? ______________________

5. How do you assess the weight of your heifers at joining?
- ☐ Weigh all heifers
- ☐ Weigh a sample of heifers
- ☐ Assess weight by eye
- ☐ Use a weigh band
- ☐ Don't assess weight of heifers

6. What is the effective land area of your farm? ______ha or ______ acres

7. What is/are the main breed(s) in your beef breeding herd?
- urebred: (specify) ____________________ ☐ Commercial ☐ Stud
- rossbred: (specify) ____________________ ☐ Commercial ☐ Stud
- omposite: (specify) ____________________ ☐ Commercial ☐ Stud

Green Section

13. How many heifers calved for the first time at 3-years of age in 2006? ____________

14. How many 3-year-old heifers did you assist at calving in 2006? ____________

15. Were these heifers put to the bull at 15-months of age?
- ☐ Did breed these heifers at 15 months, but these ones failed to conceive - go to question 17
- ☐ Did breed some heifers at 15 months, but these heifers were unsuitable to put to bull at 15 months - please go to question 16
- ☐ No heifers put to bull at 15-months - please go to question 16.

16. Why didn't you put these heifers to the bull at 15-months?
(please rate the importance of these reasons by circling a number on a scale of 1-5, 1=not important, 5=very important)

	Not important...very important
Returns don't justify extra work and costs	1 2 3 4 5
High incidence of calving difficulty in heifers calving at 2 years of age	1 2 3 4 5
Unable to grow heifers to a suitable weight for mating at 15 months (what is a suitable minimum weight? ____________)	1 2 3 4 5
Want a higher pregnancy rate than can be achieved at 15 months	1 2 3 4 5
Need a mob (empty R2 heifers) that can be fed less in winter if required	1 2 3 4 5
Concerned about rebreeding performance of 2-year-old heifers	1 2 3 4 5
Stunting of heifers' growth and mature size if mated at 15 months	1 2 3 4 5
Don't want a separate line of calves	1 2 3 4 5
Requires different management skills	1 2 3 4 5
2-year-old heifers are poor mothers	1 2 3 4 5

17. What criteria do you use for selecting bulls to mate 27-month heifers? (tick all that apply)
- ☐ Cost of bull
- ☐ Same bull as for mixed age cows
- ☐ Breed (specify:____________________)
- ☐ EBV birth weight: ☐ high ☐ low ☐ moderate
- ☐ EBV 200/400/600 day weight: ☐ high ☐ low
- ☐ EBV direct calving ease: ☐ high ☐ low
- ☐ EBV gestation length: prefer ☐ high ☐ low
- ☐ Select based on a selection index (specify: ____________________)
- ☐ Age of bull: ☐ yearling ☐ 2-yr-old ☐ mature bull
- ☐ Weight of bull at joining
- ☐ Shape of bull: ☐ smooth & narrow shoulders ☐ long body ☐ narrow & angular hips and rump

18. How did you manage calving difficulty in your 3-year-old heifers that calved in 2006 and what have you tried in the past? (tick all that apply)

	2006	Tried in the past
No particular strategies	☐	☐
Selected an appropriate bull	☐	☐
Low feeding in late pregnancy	☐	☐
Low feeding in early pregnancy/joining	☐	☐
Wintered on hill paddocks	☐	☐
Only bred from heifers above a certain weight	☐	☐
Grow heifers well up to calving	☐	☐
Generated replacement heifers from sires with a high daughters' calving ease EBV	☐	☐
Fed hay/other supplements in evening to minimise the number of heifers calving at night	☐	☐
Other (specify____________________________)		

19. Have you tried breeding heifers at 15 months of age in the past?
☐ Yes ☐ No

20. If calving problems could be eliminated, would you change your policy to breed heifers at 15 months?
☐ Yes ☐ No

21. How many 27-month-old heifers were joined with bulls in the 2006/07 breeding season?
____

22. How many bulls were joined with those heifers? ______________

23. How long was/is that joining period in 2006/07? ______________

28. Approximately how many female breeding cattle did you winter in 2006?
- Mixed age cows __________
- Rising 3-year-old heifers (if separate from mixed age cows) __________
- Rising 2-year-old heifers __________
- Rising 1-year-old heifers __________

29. If you would you be willing to take part in future surveys on heifer performance in 2007, please write your name and address below:

____
____
____
____

Thank you for completing this survey. Your responses will be used alongside results from a Meat & Wool New Zealand research trial to generate industry guidelines for managing calvin difficulty in 2-year-old heifers.

Please send the completed to survey to:

Heifer survey
Freepost 114 094
IVABS
Massey University
Private Bag 11-222
Palmerston North

HERD SIZE & TIME OF CALVING

1. How many 15-month-old heifers were joined with a bull in 2006 (to calve in 2007)? ___________

2. What was the bull to heifer ratio? _________bulls to __________ heifers

3. What was the breed of bull that was used? ________________________

4. How old was/were the bull(s)? ______________________________

5. Did you use artificial insemination in your 15-month-old heifers?

☐ No – go to question 6

☐ Yes ⇨ For how many cycles? ___________

⇨ Were the heifers synchronised? ☐ Yes ☐ No

⇨ Did you use follow-up bulls? ☐ Yes ☐ No

6. How many 15-month-old heifers were vetted-in-calf at pregnancy testing in 2007? _____________ **OR** ☐ Heifers were not pregnancy tested.

7. How many 2-year-old heifers calved in 2007? ___________

8. On what date did the **first** 2-year-old heifer calve in 2007? ___/____/07

9. On what date did the **last** 2-year-old heifer calve in 2007? ___/____/07

10. What was the breed of your 2-year-old heifers that calved in 2007?

____

11. How many **in-calf** cows (R3 & older) were wintered in 2007? _______

CALVING & ASSISTANCE OF HEIFERS

12. How many first-calving 2-year-old heifers did you **assist at calving** in 2007? ______________

13. How often do you routinely observe your first-calving 2-year-old heifers over calving?

☐ More than twice daily

☐ Twice daily

☐ Once daily

☐ Less than once daily

☐ Never

14. What criteria do you use for assisting a first-calving 2-year-old heifer?

☐ Assist as soon as you notice her calving

☐ Don't assist in any circumstances

OR (*tick all that apply*):

☐ Assist as soon as you notice the calf is not presented properly

☐ Assist after a certain amount of time has passed, regardless of whether any progress has been made (how long? _________ hours)

☐ Assist if there has been no progress after a certain amount of time (how long? _________ hours)

☐ If a heifer is calving and you need to leave her unsupervised due to other commitments

☐ No guidelines – base assistance on "gut feeling"

☐ Assist if heifer is immobile in paddock

☐ Assist if you haven't checked the heifers in a while (eg. overnight) and she appears to have been calving for a long time

15. In what circumstances do you call the vet to assist with a calving?

☐ For every heifer that requires assistance

☐ Never – if you can't get it out, the heifer is put down

OR (*tick all that apply*):

☐ For all malpresentations

☐ For most malpresentations

☐ For unusual situations (eg. rotten or deformed fetus, twins)

☐ If the calf appears too big to fit through the pelvis (without attempting to pull it yourself)

☐ If you have attempted to pull the calf without success

☐ If the birth canal feels tighter than normal

☐ If you expect a particularly valuable calf

☐ If it is a particularly valuable heifer

☐ If you are unable to attend the calving yourself

☐ I am a qualified vet, so there is always a vet assisting

16. If a heifer requires treatment to recover from a difficult calving (eg. paralysis, retained afterbirth), what is the most extreme treatment you would provide to help her recover (even if not always successful)?

☐ None – heifer is put down if she requires treatment to survive calving complications

☐ Some self-administered treatment but **no** veterinary assistance

☐ Veterinary assistance if the vet has assisted the calving or is already at the farm for another reason

☐ Veterinary assistance that requires a separate vet visit

☐ Veterinary treatment, excluding medications that have a meat withholding period

☐ I am a qualified vet, so I administer veterinary treatment

17. If a heifer is assisted at calving but survives the calving period, is she culled because of it?

☐ No, although she may be culled for other reasons

☐ Only if she doesn't rear a calf (eg. it dies or she rejects it)

☐ Only for severe cases, or where the vet has recommended it

☐ Usually

☐ Yes, always

☐ Don't record which heifers you assist, so this information is not available when making culling decisions

18. For each heifer you assisted in 2007, please complete the following table (continue over page if necessary):

Heifer	Problem	Solution	Vet?	Calf alive? At birth	Calf alive? At 4 weeks	State of heifer Immediately after assistance	State of heifer 4 weeks later
eg. 7	Calf tail first	Vet, hand pull, back feet first	Yes	Yes	Yes	Healthy	Healthy
eg. 267	Big calf	Used calf jack	No	No	No	Paralysed – had been calving all night, used hip clamps for 10 days	Dead - shot after 10 days

Heifer	Problem	Solution	Vet?	Calf alive?		State of heifer	
				At birth	At 4 weeks	Immediately after assistance	4 weeks later

Heifer Survey – Part B

CALVES

1. Do you identify calves to their dams?

- ☐ Yes, at birth
- ☐ Yes, at calf marking (ear-tagging, dehorning, castrating etc).
- ☐ Yes, at weaning
- ☐ No

2. Did any of your first-calving 2-year-old heifers reject their live calf or have no milk for their calf?

- ☐ No
- ☐ Yes – calf rejected after assisted birth (how many? __________)
- ☐ Yes – calf rejected after an unassisted birth (how many? ______)
- ☐ Yes –accepted calf but had no milk (how many? ________)

3. Do you weigh your calves at birth?

- ☐ Yes – please provide the following information:

	Calves born to 2-yr-old heifers	Calves born to mixed-age cows
Average weight		
Heaviest calf		
Lightest calf		

- ☐ No

MARKING CALVES BORN IN 2007

4. How many first-calving 2-year-old **heifers** were present at calf marking in 2007? ______________

5. How many **calves** were present at calf marking in 2007?

Born to 2-year-old heifers ________________

Born to mixed-age cows ________________

OR not possible to get separate tallies so

Born to whole herd ________________

6. What were the causes of calf losses in your 2-year-old heifers between pregnancy scanning and calf marking and how many calves were affected?

Problem	Number of calf deaths
No calf born after heifer pregnancy tested in-calf (fetal death/abortion)	
Stillborn (assisted birth)	
Stillborn (**unassisted**, but evidence of difficult birth)	
Stillborn (unassisted & no evidence of difficult birth)	
Difficult birth (born alive but died)	
Misadventure	
Mismothering	
Scours – cause undiagnosed	
Disease (name):	
Other:	

BULLS

7. What are the EBVs of the bull(s) you used over your 15-month-old heifers in 2006 (to sire the calves born in 2007)?

☐ Don't know

☐ EBV's are not available for my breed of choice

OR Please fill in the following table as much as you can:

Breed	Birth weight EBV	200-day weight EBV	400-day weight EBV	600-day weight EBV	Gestation length EBV	Direct calving ease EBV
Bull 1						
Bull 2						
Bull 3						
Bull 4						
Bull 5						
Bull 6						
Bull 7						

8. Assuming that there were several bulls available within your price range, how did you make the decision to purchase/select these particular bulls?

☐ Based decision entirely on EBVs

☐ Looked at the EBVs first, and then made sure the structure, shape, temperament and 'look' of the bull were satisfactory

☐ Looked at the structure, shape, temperament and 'look' of the bull first and then made sure EBVs were satisfactory

☐ Based on structure, shape, temperament and 'look' alone

☐ You told a bull breeder how you intended to use the bull and they recommended the bull to you

9. Will the bull(s) you use over your 15-month-old heifers ever be used over your mixed-age cows?

☐ Yes

☐ No

☐ Maybe – it depends how they performed over the heifers

HERD MANAGEMENT

10. Which term best describes the terrain on which your pregnant rising-2-year-old heifers were **wintered** in 2007?

☐ Time spent on both flat and hill paddocks

☐ Flat

☐ Rolling hill

☐ Steep hill

11. Which term best describes the terrain on which your first-calving 2-year-old heifers were **calved** in 2007?

☐ Flat

☐ Rolling hill

☐ Steep hill

12. Do you assess the weight of your heifers?

☐ Yes, all heifers – go to question 13

☐ Yes, a sample of heifers – go to question 13

☐ No – go to question 15

13. How do you assess the weight of your heifers?

- ☐ Using scales
- ☐ Assess weight by eye
- ☐ Use a weigh-band

14. If you assessed the weight of your first-calving 2-year-old heifers at any stage, what was the **average** weight of those that calved in 2007 at:

Mating (2006) ______________
Pregnancy testing (2007) ______________
Pre-calving (2007) ______________
Shortly after calving (2007) ______________
Calf marking (2007) ______________

If you ***do not*** *have a mixed age (MA) cow herd in addition to your first-calving 2-year-old heifers, please go to question 18. If you* ***do*** *have a MA cow herd, please continue with the following questions.*

15. At what stage do your first-calving heifers **first** join the MA cow herd?

- ☐ Before their first mating at approximately 15 months of age
- ☐ Prior to their second winter at approximately 18 months of age
- ☐ Prior to their first calving at approximately 2 years of age
- ☐ After their first calving, but before rebreeding at approximately 27 months of age
- ☐ After their second mating, but before weaning of their first calf
- ☐ After weaning of their first calf, prior to their third winter
- ☐ At the end of their third winter, before their second calving
- ☐ After their second calving but before rebreeding at approximately 3 years of age
- ☐ After their third mating

16. Prior to joining the MA cow herd, how are your first-calving heifers treated relative to your MA cows?

- ☐ Higher priority than your MA cows
- ☐ Similar priority to your MA cows
- ☐ Lower priority than your MA cows
- ☐ Higher priority than your MA cows until (when?) ______________ ______________ then similar priority to MA cows

17. Once the heifers have joined the MA cow herd, do you pull out light heifers or cows for preferential treatment at any stage (eg. to run separately over winter when feed is short)?

- ☐ No
- ☐ Yes, any heifers R3 or younger
- ☐ Yes, light heifers or cows of any age

CULLING POLICY

18. How many first-calving 2-year-old heifers calved **in 2006**? __________

19. How many **second-calving** 3-year-olds calved **in 2007**? __________

20. Were any of these **second-calving 3-year-olds** heifers bought in after having their first calf elsewhere?

- ☐ No.
- ☐ Yes, all of them
- ☐ Yes, some of them – how many? __________

21. If some of your heifers that had their **first calf on your farm in 2006** did not calve as 3-year-olds on your farm in 2007, what happened to them?

- ☐ All the heifers that had their first calf at 2 years of age calved again in 2007
- ☐ No heifers calved as 2-year-olds in 2006

OR (*tick as many as apply*)

- ☐ Died – how many: ___________
- ☐ Culled for failing to rear a calf – how many: ____________
- ☐ Culled because they did not get back in calf – how many: _______
- ☐ Culled because their first calf was unsatisfactory – how many:____
- ☐ Culled for temperament, injury or other reasons – how many: ____
- ☐ Sold as part of a once-bred heifer system – how many:________
- ☐ Carried over as an empty 3-year-old in 2007 – how many:_______

22. When do you cull heifers to prevent them entering your breeding herd? (*tick as many as apply*)

- ☐ When they are marked as calves
- ☐ When they are weaned as calves
- ☐ Prior to their first mating
- ☐ At pregnancy testing after their first mating
- ☐ At calving (eg. wet dries)
- ☐ Some heifers have their first calf weaned early and the heifers are fattened for slaughter
- ☐ After weaning their first calf when it is around 6-8 months old
- ☐ All heifers born/purchased enter the breeding herd

23. Will any of the calves born to your 2-year-old heifers be kept for replacements?

- ☐ No, you don't breed your own replacement heifers
- ☐ No, you will only keep calves from your MA cows as replacements
- ☐ Yes, they will be selected as replacements in preference to calves born from MA cows
- ☐ Yes, they will be treated the same as calves from your MA cows when selecting replacements
- ☐ Yes, but only if you don't get enough suitable replacements from your MA cows

Thank you for your assistance with my research. Once the survey has been completed, please return it in the return envelope provided, or send it to:

Heifer Survey
Freepost 114 094
IVABS
Massey University
Private Bag 11-222
Palmerston North